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SOMESHWAR RAO & ANDREW SHARPE

Productivity Issues in Canada

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THE RESEARCH ASSEMBLED IN THIS VOLUME is mainly the product of work undertaken by academic researchers, in addition to a few government researchers writing in a personal capacity. Industry Canada staff formulated and managed the project and provided constructive feedback throughout the process. Nevertheless, the papers ultimately remain the sole responsibility of the authors and do not necessarily reflect the policies and opinions of Industry Canada, the Government of Canada, or any other organization with which the authors or editors are affiliated.

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SOMESHWAR RAO & ANDREW SHARPE

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Preface

Productivity Issues in Canada represents the latest research by economists, academics and public policy researchers on a fundamental economic subject. This research compendium advances our understanding of the key role of productivity in strengthening the Canadian economy, in improving Canada's ability to compete in the global, knowledge-based economy, and in raising our standard of living. A more prosperous economy provides us with the means to improve the Canadian quality of life through better health care, education and environmental stewardship.

Productivity means using efficiently all factors of production — including natural resources, skilled workers and the latest technology — to produce output of goods and services. By becoming more productive, our economy grows stronger — translating into higher wages for our workers and improved quality of life for Canadians. Strong and continuous improvements in productivity are essential to maintaining our position among the world's most productive economies and ensuring that Canada continues to enjoy one of the highest standards of living in the world.

In today's knowledge-driven, global economy, productivity is increasingly driven by innovation, calling on us to continuously improve our research and technological capabilities. The 25 papers published in this volume cover a wide range of productivity topics, including issues related to innovation, investment, global links, the new economy, social determinants and implications of productivity.

I want to extend my appreciation to the Micro-Economic Policy Analysis Branch of Industry Canada for their effort in bringing you *Productivity Issues in Canada*. This research is valuable to academics, the business community and policy analysts both within and outside of government. It also helps us to understand the links between productivity, innovation and our success as a nation. This analysis by eminent researchers will help us better understand our productivity challenges and will help Canada develop better policies to become a more innovative country in the future.

ALLAN ROCK
MINISTER OF INDUSTRY

Someshwar Rao & *Andrew Sharpe*
Industry Canada — *Centre for the Study of Living Standards*

Introduction

CONTEXT

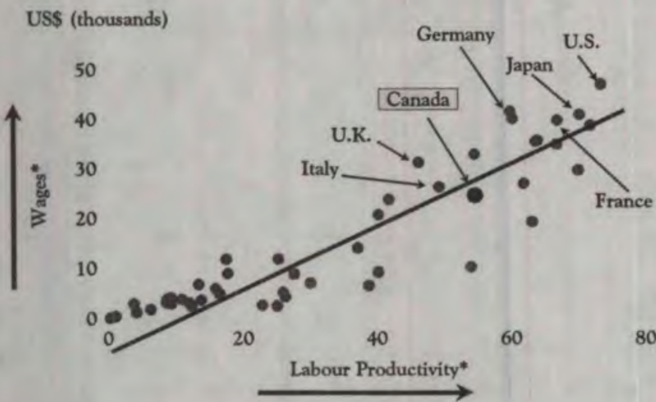
PRODUCTIVITY GROWTH IS THE FUNDAMENTAL DRIVER of improvements in real incomes and living standards over the longer term. In the short to medium term, however, changes in the size of the working age population relative to the total population, the labour force participation rate, the unemployment rate, hours of work and the terms of trade (the ratio of the average price of exports to the average price of imports) also influence trends in real incomes. But, over the longer term, the contribution of these factors to improvements in living standards is not sustainable because they have an upper limit. On the other hand, there is no limit to productivity increases. Hence, productivity growth is the main driver of improvements in real wages and real incomes. Cross-country and time-series evidence shows clearly that productivity and real wages go hand in hand (Figures 1 and 2).

Similarly, trends in relative labour productivity (real GDP per employed person or output per hour) are the key determinant of relative living standards among regions/provinces and countries over the longer term. Moreover, only stronger productivity growth relative to that of its competitors can improve a country's international competitiveness without undermining its living standards. Slower growth or a decline in real wages, and a depreciation of the currency can also enhance a country's cost competitiveness, but they adversely impact the real incomes of the population.

Small changes in productivity growth will have a large impact on living standards over the long term. For instance, with an annual productivity growth of 1 percent, real incomes double in 72 years. But, with productivity growth of 2 percent per year, real incomes will double in 36 years, and with 3 percent productivity growth, living standards will double in only 24 years. Prior to the first OPEC oil price shock in 1973, labour productivity (real GDP per employed person) increased at an average annual rate of about 3 percent in Canada.

FIGURE 1

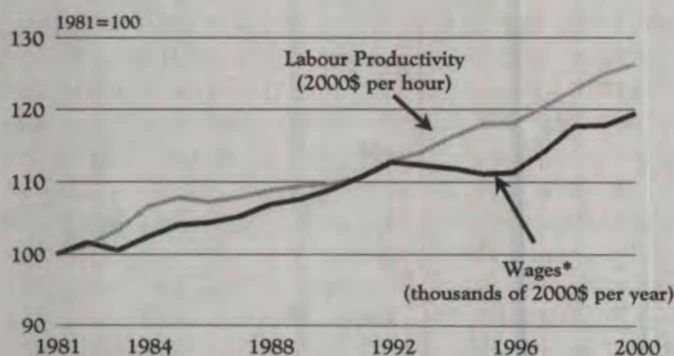
WAGES AND PRODUCTIVITY ACROSS COUNTRIES, 1997



Note: * In manufacturing.
Source: UNIDO, *International Yearbook of Industrial Statistics*, 2000.

FIGURE 2

WAGES AND PRODUCTIVITY IN CANADA, 1981-2000



Note: * Real producer labour compensation (wages/salaries plus benefits) per worker.
Source: Statistics Canada.

But, in the post-1973 period, it only increased at about 1.2 percent per year. The productivity slowdown is not unique to Canada. All other OECD countries experienced a sharp decline in productivity growth. This phenomenon has been identified as the main reason for weak real income growth, and it has contributed to the deterioration of government fiscal balances, higher unemployment and social tensions in developed economies. Despite a large body of research, the causes of the productivity slowdown are still poorly understood.

The economic well-being and quality of life of a country's citizens depend on many factors besides productivity growth. But, by increasing the economic pie, improvements in productivity offer more choices to governments and its citizens to invest additional resources in areas such as health, education, the environment and public security and infrastructure, and to alleviate poverty and economic inequalities. By contrast, in an era of stagnant real incomes, it is extremely difficult to devote more resources to these areas.

In the 1990s, Canada's productivity growth significantly lagged behind that of its southern neighbour and largest trading partner, the United States. The economy-wide gap in labour productivity level between Canada and the United States widened from about 14 percent in 1990 to over 18 percent in 2000. Similarly, the gap in real income levels between the two countries increased, averaging 20 percent in 2000. Much of the widening in the real income gap is due to an increasing productivity gap. In manufacturing — the battleground for fierce international competition — the Canada-U.S. gap in labour productivity level has grown from 21 percent in 1990 to over 35 percent in 2000 (Figure 3). Canada also lost ground to many OECD countries over the last twenty years.

This poor productivity and real income performance during the 1990s relative to that experienced by the United States has generated a great deal of research interest and fuelled a lively public debate in Canada. In November 1998, the OECD released a controversial country report on Canada in which it highlighted a situation of deteriorating productivity and living standards, forecasting more of the same for the future (OECD, 1998). The print media devoted significant space to the topic,[1] even commissioning theme issues on it (Globe and Mail *Report on Business Magazine*, 1999); the House of Commons Finance Committee (1999) and the House of Commons Industry Committee (2000) held hearings and published reports on the subject; public policy makers have focused on the formulation of a *productivity* or closely-related *innovation* agenda; government departments such as Industry Canada have undertaken or sponsored research in this area; Statistics Canada has devoted additional resources to the development of productivity data and introduced a quarterly productivity series; and think tanks have organized conferences and published studies.[2]

FIGURE 3

CANADA-U.S. PRODUCTIVITY AND REAL INCOME GAPS
(CANADA AS A PERCENTAGE OF THE UNITED STATES)

Notes: * Purchasing power parity (PPP) based.
** Real GDP per hour worked, based on the methodology of the Centre for the Study of Living Standards.
*** Real GDP per hour worked, PPP based.
Source: Statistics Canada, U.S. Bureau of Labor Statistics, and U.S. Bureau of Economic Analysis.

This volume, itself a manifestation of the heightened interest toward the productivity issue, brings together a large number of studies that Industry Canada, the lead federal department on productivity, has undertaken in-house or commissioned from outside researchers. Some of these studies have already been published by Industry Canada, several figuring prominently in the productivity debate, but many are published here for the first time.[3] Our objective is to make these studies available to a wider public. To our knowledge, this is the first compilation of research papers devoted exclusively to productivity issues in a Canadian context to be published.

This introductory chapter is organized as follows. The next section highlights each of the 25 papers published in the volume. The third section outlines the key research and policy themes emerging from these studies. It also discusses some of the important knowledge gaps that remain about the measurement and determinants of productivity growth. The concluding section pulls together the main messages that emanate from the volume. Finally, a short primer on key productivity concepts, trends and issues is provided in the Appendix for interested readers.

HIGHLIGHTS OF THE VOLUME

THE PAPERS PUBLISHED IN THE VOLUME ARE ORGANIZED into six main parts: productivity trends and determinants; innovation and productivity; investment and productivity; global linkages and productivity; productivity in the new economy; and social aspects of productivity. Each part contains a lead paper written by well-known Canadian economists. These authors were asked to do four tasks. First, pull together the main findings of the studies included in the volume under their heading. Second, integrate the results of other Canadian and international research in this area. Third, identify important research gaps, if any. Finally, spell out the research and policy implications of the key empirical findings from existing research. In what follows, we provide a brief overview of each study and review paper.

PRODUCTIVITY TRENDS AND DETERMINANTS

THE STARTING POINT FOR THE STUDY OF PRODUCTIVITY is an examination of actual productivity trends and a discussion of what determines productivity growth. This part contains six studies that do this within a Canadian context. The first, by Wulong Gu and Mun Ho, compares productivity growth in 33 Canadian and U.S. industries, on a consistent basis, over the 1961-95 period. Their main finding is a continuous deterioration of total factor productivity (TFP) growth in Canada relative to the United States, reflecting an erosion of the catch-up or convergence phenomenon. In the pre-1973 period, the rate of growth of TFP in most Canadian industries was higher than in corresponding U.S. industries; during the 1973-88 period, productivity growth was similar in the two countries; however, during the 1988-95 period, productivity grew at a slower rate in Canada in most industries.

In the second study, Frank Lee and Jianmin Tang examine differences in productivity levels and cost competitiveness between Canadian and U.S. industries. They use PPPs to estimate productivity levels and market exchange rates in order to evaluate trends in cost competitiveness. Consistent with the results of Gu and Ho about the erosion of the catch-up effect over time, they find that Canada's TFP level rose from 76 percent of the U.S. level in 1961 to 92 percent in 1980, but fell after 1985 to reach 88 percent in 1995. It is interesting to note that the TFP gap is considerably narrower than the gap in labour productivity (which was 82 percent of the U.S. level in 1995, as measured by GDP per worker, according to estimates from the U.S. Bureau of Labor Statistics), due to a greater capital intensity of production in the United States. Trends in cost competitiveness were largely determined by exchange rate movements, with competitiveness worsening from 1963 to 1976 as the value of the Canadian dollar vis-à-vis the U.S. dollar appreciated, and then improving from 1976 to 1995 as the Canadian currency depreciated.

In the third study, Serge Coulombe looks at what he calls the Canada-U.S. productivity growth paradox. He defines this as faster multifactor productivity growth within the business sector in Canada than in the United States since the early 1980s despite slower labour productivity growth in Canada, according to official Statistics Canada and Bureau of Labor Statistics (BLS) estimates. Coulombe argues that this unusual situation can be explained by the different methodologies used by the two statistical agencies for calculating multifactor productivity, with regard to labour force composition, the definition of the capital stock, and depreciation patterns. He points out that the BLS methodology is, in all three instances, superior to that used by Statistics Canada, prompting him to recommend that the latter revise the methodology it employs to calculate multifactor productivity. Since this study was originally written in 1999, Statistics Canada has in fact modified the methodology used to calculate multifactor productivity in line with Coulombe's recommendations.

In the fourth study, Serge Nadeau and Someshwar Rao look at the role of industrial structure in explaining lagging labour productivity growth in Canada relative to the United States in the manufacturing sector. They find that two industries – electronics and other electric equipment, and industrial machinery and equipment – account for the difference observed in manufacturing productivity growth during the 1990s between the two countries. These industries are larger in the United States, where they have experienced faster productivity growth. The authors attribute Canada's relative weakness in these two industries to a failure to develop at the same pace as their U.S. counterparts and they document a number of examples of this country's inferior performance in important dimensions of innovation and knowledge acquisition and use.

In the fifth study, Richard Harris provides a detailed examination of the determinants of productivity growth based on a survey of the literature. In light of what he considers overwhelming empirical evidence, he identifies what he calls the *big three* productivity drivers or levers: investment in machinery and equipment, human capital development, and openness to trade and investment. Harris puts forward three suggestions for policy makers in pursuit of greater productivity: be cautious, sticking on balance to policies that promote these three drivers; pay attention to new evidence; and be a global realist, recognizing the intense international competition for factors of production.

Erwin Diewert, in addition to synthesizing the findings of the studies published in his part of the volume, presents his own estimates of aggregate labour and total factor productivity in Canada for the period 1962-98. He finds that, for both productivity measures, the performance has been stronger in the United States than in Canada over the entire period and within four sub-periods.

One unresolved research question identified by Diewert is the possible role Canada's higher taxes and more generous social programs could play in explaining the productivity gap with the United States.

Innovation and Productivity

IT IS WIDELY RECOGNIZED THAT INNOVATION is a necessary condition for productivity advances. The five studies presented in this part provide different yet complementary perspectives on the innovation issue. The first, by Manuel Trajtenberg, asks whether Canada is missing the *technology boat* and answers affirmatively. The author bases his response on new evidence from the patent activity of Canadians in the United States. He identifies four potentially worrisome trends: i) Canada is being overtaken by a group of high-tech countries (Finland, Israel, Taiwan and South Korea) in terms of the number of patents per capita and the ratio patents/R&D; ii) relative to other countries, computers and communications — the dominant general purpose technology of our era — are underrepresented in Canadian innovation activity; iii) Canadian corporations own a relatively low proportion of Canadian innovations patented in the United States, with a high proportion owned by foreign corporations and unassigned to a legal entity; and iv) the quality of Canadian patents based on citations is lower than that of patents in the United States and other countries.

In the second study, Steven Globerman examines the linkages between the distinct yet closely related concepts of technological change and productivity growth. He defines technological change as the rate at which new production processes and products are introduced and adopted in the economy and sees it as a contributor to productivity growth. Globerman identifies a number of areas of consensus on technological change issues, including the findings that social rates of return to R&D substantially exceed private rates and that government-funded R&D has significant private sector spillover benefits. He also notes that the reasons for the low rate of return to R&D in Canada are poorly understood, as are the dynamics of the relationship between technological change and productivity growth in service industries, particularly public services such as health and education, because of the traditional focus on manufacturing.

In the third study, Someshwar Rao, William Horsman, Ashfaq Ahmad and Phaedra Kaptein-Russell examine the key drivers of innovation to shed light on the nature and sources of Canada's innovation gap. They find a strong and positive relationship between a number of innovation indicators, such as the number of patents, and real GDP per capita. They document Canada's innovation record, pointing out its particularly weak performance in terms of the machinery and equipment ratio (lowest in the G-7) and the R&D/GDP ratio (second lowest in the G-7 after Italy). One encouraging finding is that the innovation gap appears to be narrowing based on a number of indicators.

While recognizing that the Canadian government has been active in promoting innovation, they argue that more attention needs to be paid to education and training, and investment in R&D and machinery and equipment, and that our business framework and the regulatory system should be flexible, dynamic and competitive relative to that of other OECD countries, especially the United States.

In the fourth study, Randall Morck and Bernard Yeung provide a synthesis of existing research on the economic determinants of innovation. They begin by confirming the common belief that innovative countries and firms do in fact register superior economic performance. They go on to note that, in a knowledge-based economy, the primary form competition takes is innovation, not price cutting. Consequently, the perfect-competition model of economics does not apply in an environment where innovation bestows monopoly power, at least temporarily. The authors express scepticism regarding the potential benefit of government support to innovative activities of small firms because of rent-seeking, and they prefer a strategy aimed at subsidizing infrastructure and education.

Finally, in the review paper, Jeffrey Bernstein presents a detailed tour of the literature on innovation and productivity, including the four studies published in this part, with reference to measurement issues, the determinants of innovation, and innovation policy. Among the many aspects he addresses is the finding that U.S. R&D is of crucial importance to Canadian productivity growth because of its large spillover effects. He notes that there appears to be no secular decline in R&D-induced productivity gains in the United States, which bodes well for future productivity gains in Canada.

INVESTMENT AND PRODUCTIVITY

LIKE INNOVATION, INVESTMENT IS WIDELY RECOGNIZED as a key determinant of productivity growth. The three papers presented in this part of the volume examine in detail the relationship between investment and productivity. In the first, Kevin Stiroh offers a survey of investment and productivity growth from both the neoclassical and new growth perspectives. He points out that the two schools of thought diverge on the transmission mechanism through which investment increases productivity. The neoclassical approach focuses on diminishing returns to capital that are primarily internal to the firm, while new growth models emphasize increasing returns and external effects as productivity gains spillover outside the firm. He sees the two approaches as complementary, with the neoclassical focus on input accumulation and internal returns explaining up to four fifths of economic growth and the new growth theory providing an explanation for the residual one fifth associated with technological progress.

In the second study, Edgard Rodriguez and Timothy Sargent ask whether underinvestment has contributed to the Canada-U.S. productivity gap. They find that Canada underinvests significantly in R&D and in machinery and equipment by comparison with the United States, but they argue that these investment gaps do not necessarily explain much of the productivity gap. According to the authors, for the difference in R&D investment to account for the productivity gap, the social returns to R&D must be much greater than the private returns, and a large proportion of the spillovers must stop at the border. For the lower investment in machinery and equipment to explain the productivity gap, it must represent greater differences in capital quality than the current data appear to suggest. The authors believe that the case is *not proven* for these suppositions. They conclude that the productivity gap does not seem to be the consequence of underinvestment in broad aggregates, implying that policy measures such as taxes and subsidies that target these aggregates may not be the most efficient means of reducing the gap.

In the review paper, Ronald Giammarino discusses the investment-productivity relationship in the context of the overall research literature, as well as the two studies published in the volume. He argues that the standard economic approach to investment could be enriched by insights from the corporate finance field, in particular how investment decisions are made in the presence of numerous market imperfections. This approach sees informational problems as central to the firm's investment decisions and looks at the links between these decisions and such factors as internally generated capital and the legal and accounting systems.

Global Linkages and Productivity

A COUNTRY'S PRODUCTIVITY IS INFLUENCED by its economic relationships with other countries through international linkages such as technology transfers and investment and trade flows. This part contains three papers that explore the impact of these linkages on productivity. The first study, by Daniel Trefler and Gary Sawchuk, examines the impact of the Canada-U.S. Free Trade Agreement on productivity in the manufacturing sector. Their main finding is that over the 1989-95 period, tariff cuts raised labour productivity by 3.2 percent per year in the most affected industries, and by 0.6 percent per year in the overall manufacturing sector.

In the second study, Someshwar Rao and Jianmin Tang envisage whether Canadian-controlled manufacturing firms are less productive than their foreign-controlled counterparts. They answer in the affirmative, finding that multifactor productivity levels of Canadian-controlled firms were on average 19 percent below those of foreign-controlled firms over the period 1985-95. They also find that conventional determinants of productivity differences such as labour quality, unionization, export orientation, and firm size do not account for the productivity gap. Rather the authors suggest that the difference is attributable to superior management practices and strategies and to the technological know-how of foreign-controlled firms.

In his review paper, John Ries provides an overview of the recent literature on foreign investment, trade, and industrial performance, and relates this material to the two studies published in this part of the volume. He notes the theoretical prediction that trade can lead to both static and dynamic gains in productivity growth, with reallocation of labour toward higher productivity industries being particularly important. In contrast, he points out that the empirical literature fails to verify consistently that openness to trade or the volume of trade are associated with greater productivity growth within countries, although many — if not most — studies, such as that of Trefler and Sawchuk, do find a positive relationship.

PRODUCTIVITY IN THE *NEW ECONOMY*

THE ACCELERATION OF LABOUR PRODUCTIVITY GROWTH in the United States in the second half of the 1990s has lead to talk of a *new economy*, defined as one of permanently higher trend productivity growth fuelled by the productivity-augmenting effects of information technologies. The five papers presented in this part of the volume explore various dimensions of the new economy debate. The first, by Steven Globerman, defines and assesses the linkages between electronic commerce and productivity growth. While recognizing that electronic commerce is still at an early stage of development, the author believes that its economic consequences are likely to be evolutionary rather than revolutionary. Given the evidence to date of only limited spillovers from e-commerce, Globerman argues that there is little theoretical justification for emphasizing the promotion of e-commerce as a public policy goal.

The second study, also by Steven Globerman, examines the phenomenon of industrial clusters, given the growing perception that economic activity in knowledge-intensive sectors is characterized by regional clustering. As these activities are attracted to locations offering high levels of human capital and well-developed physical and social infrastructure, they could in principle be created in many places. Hence, governments could foster their formation through human capital and infrastructure development. Nevertheless, Globerman takes a *laissez-faire* approach to clusters, arguing that governments should not try to determine what location-specific clusters should be promoted, but that they could legitimately rationalize or mediate the competing claims of regions for public support. In the author's view, the greatest practical challenge facing the federal government is to use its leverage with the provinces to discourage wasteful competition to attract clusters.

The third study, by Andrew Sharpe and Leila Gharani, surveys the literature on trend productivity growth and the new economy. It examines the productivity revival in the United States since 1995, noting that service industries, such as trade and finance, are now finally experiencing improved productivity growth, thanks to their extensive investment in information technologies. They assess the views of new-economy advocates, such as Dale Jorgenson, and of its critics, such as Robert J. Gordon. The authors take a middle-of-the road position on the new economy. They attribute about half of the one percentage point acceleration in labour productivity growth during the second half of the 1990s to temporary or short-term factors such as the strength of the economy and the investment boom, and the other half of the permanent upward shift in trend productivity to the adoption of information technologies.

In the fourth study, Ronald Hirshhorn, Serge Nadeau and Someshwar Rao examine and assess the role of government with regard to innovation in a knowledge-based economy. They begin by noting that in 1996-97, the federal government allocated over $7 billion to support scientific and technological activity through direct expenditures and tax relief. They point out that the rationale for government involvement in innovation is the market failure arising from the positive spillovers or externalities generated by private sector R&D. According to the authors, it is difficult to make the case that Canada is providing inadequate encouragement for innovation through tax incentive schemes and intellectual property laws. Indeed, they argue that it is not clear Canada is better off having a more generous system of R&D subsidies than other countries, and that we might be better off by rebalancing government R&D support toward lower corporate taxes and reduced tax credits and subsidies.

In the review paper, Peter Dungan and Thomas Wilson synthesize the debate on the new economy and discuss its implications for future productivity growth in Canada. While sharing in part the optimism of the new economy school, they argue that it is inappropriate to project for Canada the same rate of productivity growth that the United States has enjoyed since 1995. The authors believe that the superior U.S. productivity performance is not reproducible in other countries due to the large size of the information technology sector in that country and unique factors on the demand side. If the pattern of productivity growth in Canada in the first decade of this century were to track developments in the United States in the second half of the 1990s, they project that annual growth in output per worker will be around 1.8 percent, which would be a better performance than in each of the three previous decades.

SOCIAL DETERMINANTS OF PRODUCTIVITY

ASIDE FROM ECONOMIC DETERMINANTS, social factors can also influence, both directly and indirectly, productivity growth. The three papers presented in this part of the volume explore a number of dimensions of the social determinants of productivity. The first study, by Richard Harris, offers a comprehensive discussion of the linkages between social policy and productivity growth. The author points out that if it can be established that social determinants are a quantitatively major factor in productivity growth, then the traditional equity-efficiency trade-off would not exist. After an extensive review of the literature, Harris concludes that we do not yet have clear evidence of robust linkages running from social policy and equality to productivity growth, although he recognizes that the possibility of such linkages certainly exits and is a subject worthy of further investigation.

In the second study, Andrew Sharpe analyzes the two-way relationship between productivity and economic well-being, which is defined in terms of four components or dimensions: consumption, the stock of wealth, equality and economic security. The author examines how each component can be positively influenced by higher productivity and how, conversely, improvements in certain components of economic well-being, such as equality and economic security, can feed back to foster productivity growth. The study serves to remind us that the importance of productivity goes well beyond raising real incomes as it can have important positive effects on other components of economic well-being.

In the review paper, Lars Osberg looks at the social aspects of productivity in the context of the general literature and the two studies presented in this part of the volume. He argues that the production process occurs within a social context, whose characteristics heavily influence the amount of labour and capital directly required to produce a given amount of goods and services. The author notes that unpriced inputs, such as the environment or social capital, are currently not factored into productivity measurement, but should be for a full accounting of economic and social inputs and outputs. He concludes by recommending that one of the priorities of future productivity research be a more accurate identification and measurement of these unpriced inputs.

KEY EMERGING THEMES OF THE VOLUME

IN A VOLUME CONTAINING 25 PAPERS and extending over 800 pages, a large number of issues are discussed. This section identifies and highlights for the reader a select number of issues that the editors consider particularly important. A key criterion used in their choice is the frequency with which these issues are discussed by the contributors to the volume.

ACCURATE MEASUREMENT IS CRITICAL

AS THE FIRST PAPER BY RICHARD HARRIS stresses, in the productivity field "measurement is everything." If we cannot produce reliable and accurate productivity estimates, then we cannot intelligently discuss productivity trends and determinants. A large number of measurement issues face productivity researchers, including: the quality adjustment of prices and the contribution that *hedonics* can make in this area; the quality adjustment techniques for labour and capital; the development of improved service sector output measures, especially for finance and insurance and for non-marketed output in education, health and public administration; the choice of appropriate capital stock depreciation rates; and the estimation of PPPs for international productivity-level comparisons.

The study by Serge Coulombe demonstrates clearly the importance of productivity measurement for reliable international and inter-temporal comparisons. The author shows that the key question of whether Canada has experienced better or worse business sector multifactor productivity growth relative to the United States depends crucially on the definitions and assumptions behind the productivity numbers. There has been a great deal of debate in Canada about the size and the widening of the Canada-U.S. labour productivity level gap. But, the size of this gap depends critically on the estimated value of the PPP exchange rate. We also need detailed estimates of PPP exchange rates by industry to make international productivity comparisons at the industry level.

It is encouraging to note that the importance of measurement issues is increasingly recognized by all parties with an interest in productivity, including statistical agencies, international organizations, government departments and academic researchers. Indeed, Statistics Canada has devoted additional resources to the development of better productivity data for the Canadian economy.

Nevertheless, the quality of productivity data for many service industries in Canada and other OECD countries is not very good. Measured productivity growth in a number of service industries, such as business services, personal services, education, health and public administration, has been weak or even negative. It is unclear whether these trends reflect the true state of productivity advances in these sectors or problems associated with the measurement of real output. With the service sector already accounting for three quarters of total employment and this share still rising, it is important to measure accurately service sector productivity. Productivity measurement problems in the non-market sector are particularly severe. For example, labour inputs are used to measure real output in public administration, with the result that productivity growth is assumed to be zero. With the introduction of information technologies, it is likely that there have been productivity gains in public administration. Further work in this area should be a top priority for productivity researchers.

In view of the growing importance of service industries globally, especially knowledge-based services, more accurate and internationally comparable productivity estimates for service industries are extremely important for reliable international and inter-temporal comparisons. Statistics Canada should work more closely with other statistical agencies and the OECD towards developing more accurate estimates of output and productivity in service industries as well as detailed estimates of PPPs by industry on a regular basis.

CANADA HAS LOST SIGNIFICANT GROUND TO THE UNITED STATES

A NUMBER OF STUDIES PUBLISHED IN THIS VOLUME, especially those of Lee and Tang, and of Nadeau and Rao, address the issue of Canada's productivity gap with the United States. There is general consensus that Canada's aggregate labour productivity (GDP per person-hour worked) is significantly (about 20 percent) below that of the United States, and that the gap has widened during the 1990s. Similar results are obtained for total factor productivity comparisons. In addition, most industries have lower productivity levels in Canada than in the United States. It is particularly acute in the manufacturing sector, where Canada's labour productivity level is currently more than 35 percent below the U.S. level. However, Canada does have a productivity level advantage over the United States in primary and resource-based manufacturing industries.

It is important to note that the lion's share of the disparity in living standards, measured by GDP per capita, between Canada and the United States can be explained by the productivity gap. No consensus has emerged on the causes of the productivity gap, although many factors have been put forward as possible explanations. However, the study by Nadeau and Rao shows that the weakness of Canada's high-technology sector relative to that of the United States is the main reason behind the growing manufacturing productivity gap in the 1990s.

The continued widening of the productivity gap could have adverse consequences on Canada's future trend productivity growth by increasing the flow of investment, R&D spending and skilled labour going to the United States. Under this scenario, there is a risk that Canada could slide into a vicious cycle of weak economic performance relative to the United States. Future research should explore empirically the dynamics and interrelations among the Canada-U.S. productivity gap, investment, innovation, human capital, industrial structure and trend productivity growth.

Another key area for future research is that of Canada-Mexico productivity level comparisons. Mexico is emerging as a major North American player. Its share of U.S. imports almost doubled between 1990 and 2000. It has a huge labour-cost advantage over Canada and the United States. Mexico has made strong inroads in high-tech exports. Mexico and Canada depend heavily on the

U.S. market for trade, investment and higher value-added activities. Hence, it is important to understand the evolution of Mexico's productivity performance and its comparative advantage vis-à-vis that of Canada, because of their potential impact on Canada's industrial structure and productivity. A detailed industry-level comparison of Canadian and Mexican productivity levels and their trends over time would be extremely useful in this regard.

Information and Communications Technologies Made a Major Contribution to Canada's Productivity Growth in the 1990s

An issue that permeates virtually all studies presented in this volume is the impact of information and communications technologies (ICTs) on productivity. During the 1990s, all developed countries have witnessed the introduction of ICTs into the workplace on a massive scale. The obvious question is whether this development has lead to faster productivity growth. In approaching this issue, it is important to distinguish between the contribution to productivity growth from the ICT-producing sector, especially the computer and telecommunications equipment manufacturing industries, and the contribution from the ICT-using sectors, which comprise virtually all other industries.

The ICT-producing sector has contributed significantly to labour productivity growth in both Canada and the United States during the 1990s. For instance, more than a quarter of aggregate labour productivity growth in Canada over the last decade was due to the superior productivity performance of the ICT-producing sector. In the United States, the contribution of this sector to aggregate productivity growth was even larger. In fact, the differences in size and productivity growth of the ICT-producing sectors between the two countries was largely responsible for the widening of the Canada-U.S. manufacturing productivity gap over the last decade.

As for the impact of ICTs on productivity growth in ICT-using industries, the available empirical evidence is mixed. There seems to be a general consensus that labour productivity growth in the United States increased dramatically during the second half of the 1990s in many service industries, including wholesale and retail trade and financial services, which are heavy users of ICTs. This evidence provides support to the argument that the massive investments in ICTs are finally paying productivity dividends. But, the evidence from other OECD countries, including Canada, is inconclusive at best. Unlike the United States, aggregate labour productivity growth did not increase during the second half of the 1990s in many OECD countries, despite a strong contribution from the ICT-producing sector. This trend implies that there was either no increase or a small decline in the average productivity growth of ICT-using industries in these countries.

Two key research questions emerge from the recent U.S. experience. First, is the pace of productivity advances during the second half of the 1990s in the United States (now estimated at 2.4 percent per year in the business sector) sustainable? Second, why did ICT-using industries not register an increase in trend productivity growth outside of the United States? The recently launched joint research project by Industry Canada, Statistics Canada and Dale Jorgenson of Harvard University will explore these two issues in detail.

No Consensus on Canada's Trend Productivity Growth

THIS ISSUE, CLOSELY RELATED TO THE PRECEDING DISCUSSION, merits separate treatment because of its importance for a Canadian audience. Official data from Statistics Canada show that output per hour in the business sector increased at an average annual rate of 1.7 percent in the second half of the 1990s, up only 0.2 points from 1.5 percent during the first half of the decade. This suggests that trend productivity has not picked up significantly in Canada during the 1995-2000 period, as was the case in the United States. But the 1990s saw a significant improvement in productivity growth of around one half of a percentage point, from 1.1 percent per year between 1973 and 1989 to 1.6 percent from 1989 to 2000. From this longer-term perspective, trend productivity growth in Canada seems to have picked-up.

The trend productivity growth that Canada can expect to experience in the first decade of the 21st century is, of course, uncertain and subject to debate. Some observers such as Peter Dungan and Tom Wilson see little change on the horizon, projecting a continuation of the current trend of around 1.8 percent per year for aggregate labour productivity growth. Others such as Andrew Sharpe and Leila Gharani believe that trend productivity growth will rise to 2 percent or more largely because Canadian industries too will reap the productivity benefits of ICTs, although with a lag. However, even under an optimistic scenario, Canada may not register a significant increase in productivity growth well into the decade because of the cyclical downturn in productivity expected at least in 2001 and 2002 and of the potential negative impact of the slowdown in economic activity on investment and R&D spending.

Canada Needs to Close the Innovation Gap

A NUMBER OF STUDIES PUBLISHED IN THIS VOLUME, especially that of Manuel Trajtenberg, and that of Someshwar Rao, William Horsman, Ashfaq Ahmad and Phaedra Kaptein-Russell, expose the weaknesses of Canada's innovation performance, suggesting that Canada's productivity problem is closely related to its problems on the innovation front. Canada fares poorly on a number of key innovation indicators, particularly the quantity and quality of patents, the ratio of R&D to GDP, the ratio of machinery and equipment investment to GDP, the adoption of new technologies and the commercialization of innovations. It is clear that Canada needs to address its innovation gap. But, there seems to be no general agreement among researchers on the precise causes of this gap.

A number of studies found in this volume, especially that of Jeffrey Bernstein, the first study by Steven Globerman, and the one by Randall Morck and Bernard Yeung, shed some light on the reasons for the R&D shortfall, particularly in light of the generous tax treatment and subsidies such expenditures receive. One explanation advanced is that Canadian firms feel less compelled to undertake R&D because they can access new technologies from abroad in a more cost-effective manner, either from their parent firm if they are foreign-owned or through a licensing agreement if they are Canadian-owned. A second explanation, following from Nadeau and Rao's analysis of the role of industrial structure, is that the relatively small size of the R&D-intensive high-tech sector in Canada may mean that less R&D takes place.

Despite many years of research, a satisfactory explanation of Canada's low level of private sector expenditures on R&D has proven elusive. The reasons behind the low take-up rate for the various benefit programs, such as an excessively narrow definition of eligible R&D expenditures, are poorly understood. Equally, the relative importance of the various factors affecting R&D, such as industrial structure, foreign ownership, and venture capital supply, merit closer attention from researchers.

In addition, an important question to explore is why Canadian firms are not investing as much as their counterparts in the United States and other OECD countries in machinery and equipment and in the commercialization of innovations. The role of taxes and incentives, the regulatory burden, the infrastructure, managerial practices and strategies, competition, framework policies and institutions in Canada's innovation process vis-à-vis the United States and other OECD countries should be analyzed in detail so that more effective policies can be developed to close this country's innovation gap.

The available research suggests that Canada has proportionately more small and medium-sized enterprises (SMEs) and that they account for a larger share of output and employment than in the United States. It shows also that SMEs in general are significantly less innovative and productive than larger firms. Therefore, a better understanding of the factors behind the relatively weak innovation performance of SMEs might also shed more light on the reasons for Canada's aggregate innovation and productivity gaps. Despite the growing importance of service industries in the economy, there has been little research until now on the innovation dynamics and performance of these industries in Canada and other OECD countries. We also need to know how well

Canadian industries are performing relative to their counterparts in the United States and other OECD countries.

Increased Outward Orientation Has Been Good for Canada's Productivity

THE IMPORTANCE OF INTERNATIONAL TRADE and foreign direct investment (FDI) for the Canadian economy has increased considerably during the 1990s. Exports of goods and services currently account for more than 45 percent of Canada's GDP, up from 30 percent just a decade ago. The share of imports in GDP has similarly risen. In addition, the ratios of inward and outward FDI stocks to GDP have also increased dramatically over the past decade. The buoyant U.S. economy, the FTA/NAFTA and the globalization of business have all contributed to the increased outward orientation of Canadian firms and the Canadian economy.

Economic theory predicts that an increased outward orientation will stimulate productivity by intensifying domestic competition, facilitating technology and knowledge transfers, and increasing specialization. However, aggregate productivity trends seem to suggest that increased outward orientation, and especially stronger North American economic linkages, did not have a positive impact on Canada's productivity performance in the 1990s. The Canada-U.S. productivity gap actually widened during that period.

But we cannot rely on simple aggregate data to make judgements about the relation between outward orientation and productivity, because productivity trends are influenced by a large number of factors, including outward orientation. Therefore, we need to disentangle the influence of outward orientation and other variables. The research by Trefler and Sawchuk and by Rao and Tang does precisely this. Their results clearly show that increased trade and investment orientation has had a positive effect on Canada's productivity growth. These findings are generally consistent with other studies in Canada and other countries. The implication of these findings is that Canada should maintain its market-oriented policies on both the domestic and international fronts, but that it needs to address the challenges related to investment and innovation. In addition, researchers and government need to better educate the general public about many of the misperceptions concerning increased outward orientation and Canada's productivity performance.

The available research generally shows that foreign-controlled firms in Canada are more productive than domestically controlled Canadian firms, even after controlling for the influence of factors such as size, industry, unionization, and investment and R&D intensities, presumably because of technology and knowledge transfers from their parent companies. But foreign-controlled firms can have positive technology and knowledge spillovers on domestic firms via their client/supplier relations. Increased competition from foreign firms may also stimulate innovation and increase technology adoption within domestic firms. Additional research is needed to shed light on these spillover mechanisms linked to inward FDI and their contribution to Canada's productivity. We also need to better understand the consequences of increased outward investment for Canada's innovation and productivity performance.

Productivity Growth is Important for Improving Quality of Life

The studies by Harris and Sharpe presented in the last part of the volume provide national and international evidence showing the positive influence of productivity growth on social outcomes and quality of life. Higher productivity growth expands the economic pie and offers more choices to government and society to spend additional resources on education, health and the environment, and to fight poverty, reduce income inequalities and strengthen the social safety net. On the other hand, slower productivity growth constrains significantly the ability of government to invest in activities that enhance the quality of life of its citizens and mediate social tensions.

But the research to date is not conclusive about the potential positive feedback on productivity of improved social outcomes and quality of life. However, as expected, the available research shows that investment in human capital is very important for productivity. But there is no consensus on the impact of reduced income inequalities and improved social cohesion and quality of life on productivity. At this stage, the dynamics of the social determinants of productivity are poorly understood. While some work is underway in this important but relatively unexplored area, additional in-depth research is needed.

Government Can Play an Important Role

Although productivity improvements are primarily the result of numerous decisions and strategies of individuals, households and firms, governments can play an important facilitating role. The study by Hirshhorn, Nadeau and Rao discusses the role of government in stimulating innovation and increasing trend productivity growth. Because of the public-good nature of investments in education, health, and physical and knowledge infrastructure, there will be serious underinvestment in these productivity-enhancing activities without the support and active involvement of governments. Another important means by which governments can influence productivity is by improving the business climate for investment, innovation, entrepreneurship and risk-taking via efficient regulations, competitive and flexible tax and market framework policies, sound industrial policies and freer trade. Governments can also play an important role toward improving the productivity performance of SMEs by helping them enter the export market, obtain access to capital at a reasonable cost and adopt technology. Governments can also contribute to strengthening the linkages between businesses, universities and government laboratories, and to expanding the commercialization of innovations.

The Canadian government has undertaken a number of initiatives to encourage R&D spending, stimulate innovation, facilitate the creation, diffusion and use of knowledge, promote the commercialization of innovations in Canada, and encourage the adoption and diffusion of new technologies. These measures include generous R&D tax incentives, the Canadian Foundation for Innovation, the Canadian Institutes of Health Research, the Network of Centres of Excellence Program, the Industrial Research Assistance Program, Technology Partnerships Canada, Investment Partnerships Canada, SchoolNet/Community Access Program, and the Canada Research Chairs Program. In addition, in the January 2001 Speech from the Throne, the federal government announced its commitment to double federal R&D spending by 2010. Furthermore, recent fiscal measures have been designed to make the Canadian tax system more competitive and supportive of innovation and risk-taking.

Despite the above initiatives, it is widely recognized that the policy environment and the programs aimed at stimulating productivity growth could still be improved. While this volume is not strictly speaking a policy-oriented publication, it provides much insight on the most appropriate policy framework for productivity advance. Indeed, the findings and policy recommendations found in the 25 chapters of the volume are presented by recognized productivity experts and have important implications and relevance for public policy and private sector action to improve productivity. In this section, we provide a brief summary of these findings and recommendations.

Economists who are influenced by the neoclassical growth school tend to consider intervention seldom appropriate. They believe that margins are optimized and that few externalities or spillovers exist, so there is limited rationale for intervention. On the other hand, economists who subscribe to the new or endogenous growth school see markets, particularly for technology, as unreliable because of imperfect information and appropriability problems. They believe that the resulting market failures can be corrected by appropriate policy.

The traditional approach to industrial policy of picking individual sectors and firms as potential winners is soundly rejected by the studies published in this volume. Even subsidies to the high-profile e-commerce sector are considered bad policy. Contributors strongly prefer framework policies that improve the overall business environment, such as lower taxes, greater openness to trade and investment flows, including reduced barriers to foreign investment in certain protected sectors, and fewer restrictions on technology transfers.

No study has assessed the appropriateness of the federal government's goal of doubling the R&D/GDP ratio by 2010 and the policies and programs it intends to use in order to attain this goal. Given the already generous (too generous according to some authors) level of R&D incentives, contributors thought that the most effective measure the government could take to increase R&D would be to lower corporate tax rates.

Although there is wide recognition that no panacea or golden bullet exists to improve productivity performance, policies in the area of human capital development emerge as a top priority. There are, however, few specific suggestions about the nature of policies and programs that would have the greatest impact on productivity.

A recent initiative in the United Kingdom is relevant to Canada's productivity, innovation and skills agendas. In order to meet the productivity challenge, the U.K. government (U.K. Department for Education and Skills, 2001) recently announced an innovative policy of funding private sector-led skills councils to work at the sectoral level to develop skills and improve productivity. The rationale for this initiative is threefold: first, given the differences among sectors, productivity improvement is most effectively approached at the sectoral level; second, skills development, an essential ingredient of productivity improvement, is also best approached at the sectoral level; and third, such an initiative is most effectively led by private sector parties, given their first-hand knowledge of the sector and strong interest in the success of the policies.

A final key message from the volume is that while policy initiatives should certainly be assessed and evaluated from the point of view of their impact on productivity, it is the impact of these policies on society's well-being that is more important in the final analysis. Productivity makes a significant contribution to well-being and quality of life, but it is not their only determinant by far. These limitations of the productivity agenda for improving societal well-being in no way reduce its importance, they merely serve to put it in perspective.

Conclusion

PRODUCTIVITY GROWTH IS THE FUNDAMENTAL DRIVER of improvements in real wages and real incomes in the long term. Canada, like other OECD countries, experienced a dramatic slowdown in productivity in the post-1973 period, the causes of which are still not very well understood. Nevertheless, business sector labour productivity growth increased somewhat in Canada in the 1990s. But despite increased outward orientation and many structural policies, the Canada-U.S. labour productivity and real income gaps widened significantly during the 1990s. These unexpected and worrisome trends stimulated considerable research interest and a lively public debate in Canada.

Industry Canada commissioned a large number of studies to better understand the reasons for Canada's relatively poor productivity record. The present volume is the result of this research effort.

In this introductory chapter, we have presented the highlights of all 25 papers, outlining some of the key common themes that emerge from the studies, and pointing to some of the remaining gaps in our knowledge. These papers provide a rich body of information on productivity trends in Canada, Canada-U.S. productivity comparisons, the possible causes of Canada's relatively weak productivity performance, the contribution of ICTs to productivity growth, and the role of government in raising trend productivity growth.

Here are the key messages emanating from the research reported in this volume: accurate measurement of productivity is critical to understanding and analyzing Canada's productivity problems and developing appropriate policies and strategies; Canada has lost significant ground in productivity and real incomes to the United States in the 1990s; Canada needs to pursue effective policies and strategies to close the innovation gap; the ICT-producing sector contributed in a major way to Canada's aggregate productivity growth, but there is no strong evidence of a pick-up in productivity growth in ICT-using industries; there is no consensus on whether trend productivity growth in Canada has increased; greater outward orientation has been positive for productivity in Canada; productivity growth can improve social outcomes, social cohesion and quality of life, but there is no consensus about the positive feedback on productivity performance of investments in social programs; finally, government can play an important role in increasing productivity growth.

ENDNOTES

1 According to the InfoGlobe database, the term *productivity* appeared in *The Globe and Mail* in 658 articles in 1999 and 622 articles in 2000, up from 527 articles in 1998 and an annual average of 514 articles over the 1994-98 period.

2 For example, the Centre for the Study of Living Standards organized a major international conference on the Canada-U.S. manufacturing productivity gap in January 2000. The papers are available at www.csls.ca under Past Events and will be published in an edited volume in 2002.

3 Of the 25 papers assembled in this volume, including 6 overview papers, 11 have already been or are being published as working or discussion papers by Industry Canada.

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APPENDIX

A PRIMER ON PRODUCTIVITY CONCEPTS, TRENDS AND ISSUES

A FRUITFUL OR PRODUCTIVE READING of the papers published in this volume requires a certain level of knowledge of productivity concepts, trends and issues. While this introduction cannot impart such knowledge on the reader unfamiliar with economics in general and the topic of productivity in particular, it does provide a brief primer which reviews basic information on productivity that repeatedly comes up throughout the volume. Hopefully, this information will benefit the reader who has some but less than a complete background in the productivity field.

THE MEANING OF PRODUCTIVITY

OF COURSE, THE STARTING POINT FOR A VOLUME ON PRODUCTIVITY must be the definition and meaning of that term. In its essence, productivity is the ratio or relationship between a measure of output and the inputs that were used to produce that output.

A fundamental distinction is made between partial and total productivity measures. The former relate output to only one input, such as labour or capital, even though it is recognized that other inputs contributed to output. Labour productivity is the best-known partial productivity measure. The latter measures relate output to a combination of inputs, such as capital and labour. These measures are known as total factor or multifactor productivity and represent the growth in output not accounted for by input growth.

A key issue in total factor productivity measurement is the weighting of inputs. Under competitive conditions, the income share of a factor of production is normally considered the relative contribution of that factor to output and is consequently used to weight the factor in calculating an index of total input, or the growth rate of the index. When markets are not competitive, the weighting issue is much more complex.

The meaning of total factor productivity is also controversial. Some economists interpret it as a measure of overall technological change, others as a measure of disembodied technological change, that is technological change that is not embodied in new machinery and equipment, and still others see it as essentially a meaningless concept (Lispey and Carlaw, 2000).

A second important distinction is between the level of productivity and productivity growth. The former refers to the output per unit of input at a given point in time. An example would be the level or value of output per hour for the total economy in 1999, says $20, expressed in constant 1997 prices. The latter measure represents the percentage change in output levels, expressed in constant prices, between two points in time. An example would be a 5 percent increase in labour productivity between 1999 and 2000 when the level or value of output per hour rises from $20 to $21. One often hears the complaint that Canada's productivity is poor. This could be referring to a situation of a low aggregate productivity level or a low productivity growth rate, or both. It is important that commentators specify whether they are referring to levels or growth rates as their implications can differ significantly.

Labour input can be measured either in terms of the average annual number of workers or in terms of the total number of hours worked in a year. It is important to specify which concept of labour productivity is being employed. The growth rates of output per worker and output per hour worked may differ when there is a change in the number of hours worked over time. Indeed, the large fall observed historically in the average working time per worker has meant that output per hour has grown significantly faster than output per worker. Equally, international productivity comparisons may differ greatly when annual hours worked vary across countries. The greater number of hours worked annually by American workers compared to those of many European countries means that productivity measures based on output per worker portray U.S. productivity levels in a much more favourable light than estimates of output per hour worked.

PRODUCTIVITY TRENDS

ONE PART OF THE VOLUME IS DEVOTED to productivity trends so the discussion of trends in this section will be brief and to the point. Three distinct productivity trends or stylized facts can be identified in the post-war period for the United States and two for other developed economies including Canada. From 1945 to 1973, developed countries experienced a golden era of productivity growth, with labour productivity growth advancing 3 percent or more per year. After 1973, virtually all developed countries entered a period of slower productivity growth. Economists have still not reached a consensus on the causes of this productivity slowdown. The failure of productivity to pick up in the first half of the 1990s despite the introduction of information technologies lead observers to coin the expression *productivity paradox*. Since 1995, the United States has entered a period of much stronger productivity growth, resolving the productivity paradox as least for that country. This development is referred to and analyzed in a number of the papers in the volume. However, there is little evidence that productivity growth has picked up significantly outside the United States.

PRODUCTIVITY ISSUES

IN THE INTRODUCTION, there is a detailed discussion of some of the key issues that emerge from the studies published in the volume. Here, we highlight a small number of the more basic productivity issues that the reader should be familiar with.

International comparison of productivity levels requires that levels expressed in domestic currencies be converted to a common currency. This conversion can be done with either market exchange rates or exchange rates based on PPPs, that is the exchange rate that equalizes the price of a basket of goods and services between two countries. For accurate productivity level comparisons, it is imperative that PPPs be used, although the development of reliable PPPs is a complex task, particularly at the industry level. The existence of a range of PPPs produced by different agencies and researchers means that there is a range for relative productivity level estimates.

Statistical agencies revise regularly the economic series they produce. As productivity estimates draw upon a wide range of economic data, including estimates of employment, hours worked, nominal output, prices, and capital stocks, they are subject to frequent, and often large, revisions. Indeed, these revisions are the scourge of productivity analysts, but a necessary evil since the most recent data must be used. Unfortunately, the revision of productivity data can result in the rewriting and reinterpretation of productivity trends.

Two examples will serve to illustrate this point. In May 2001, Statistics Canada released its Aggregate Productivity Measures data, which showed that output per hour in the business sector advanced at a 1.2 percent average annual rate from 1995 to 2000, a performance characterized as weak by productivity analysts. Later that same month, Statistics Canada released new estimates of the national accounts, using for the first time the Fisher chain index and capitalizing software expenditures. These changes boosted productivity growth by a very significant 0.5 percentage points to 1.7 percent per year for the same period, which forced productivity analysts to change their characterization of productivity growth as weak over the period.

In July 2001, the U.S. Bureau of Labor Statistics revised its estimates of business sector output per hour based on new national accounts data from the Bureau of Economic Analysis. Instead of increasing at 2.8 percent annually over the 1995-2000 period as originally reported earlier that year, productivity growth was revised downward to 2.4 percent per year. This indicates that the acceleration in productivity growth was less than previously believed.

Productivity fluctuates with the business cycle. Because of the existence of overhead labour, it tends to fall during downturns and rise during recoveries since employment adjusts less quickly than output. The studies published in this volume are much more concerned with long-run than with short-run productivity trends and determinants, so the movement of productivity within a business cycle is not a key consideration. Nevertheless, two points should be noted. First, with the Canadian economy in late 2001 entering a period of weak growth due to falling aggregate demand, slower productivity growth can be expected for cyclical reasons. This does not mean that long-term productivity growth has necessarily deteriorated as any productivity shortfall now can be recovered later in the cycle. Second, to minimize the impact of cyclical influences on productivity, growth rates should be calculated at comparable points of the cycle, preferably on a peak-to-peak basis.

Productivity researchers produce a massive amount of numbers to explain productivity trends and non-specialists often have difficulty interpreting the estimates, and particularly differences between estimates. One important reason for these differences is that some researchers adjust labour and capital inputs to account for changes in quality, while others do not. The advantage of this adjustment is that quality improvements increase the growth rate of the input and hence its contribution to output. It also reduces the size of the residual, or total factor productivity, shedding more light in the eyes of some on the sources of growth. The disadvantage of such adjustment, or the advantage of not adjusting, is that the inherent conceptual and methodological difficulties are avoided and the productivity figures are easier to interpret and understand.

An important issue in the productivity field is that of productivity convergence or catch-up. The idea is very simple, namely that countries not on the technological frontier have the potential for faster productivity growth than the country or countries on the frontier because they can import the best practice technologies from the leader(s), generally the United States. The catch-up phenomenon has been seen as the major reason why most OECD countries experienced faster productivity growth than the United States during the post-war period. It is important to note that productivity convergence is by no means an automatic process as many low productivity level countries have weak productivity growth. To exploit the potential for catch-up, a country must have an economic environment conducive to economic development. But productivity convergence does not always take place, even in countries with conditions favourable to growth. With the acceleration of productivity growth in the United States during the second half of the 1990s, the productivity leader bound ahead of the followers and increased its productivity advance, a situation that can be characterized as *productivity divergence*.

Part I
Productivity Trends and Determinants

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Productivity Trends and Determinants in Canada

INTRODUCTION

IN THE FIRST PART OF THIS REVIEW, we will attempt to cover the following three topics:

- What is the evidence on economy-wide productivity growth for the United States and Canadian economies over the period 1962-98?
- What proportion of real output growth in Canada during those years is due to total factor productivity (TFP) growth and what proportion is due to the growth of primary inputs and changes in the terms of trade?
- What are the factors that explain TFP growth?

In the next section, we will review both the growth of labour productivity (output per hour worked) in the United States and Canada, and the growth of TFP.[1] Total factor productivity is the ratio of an index of outputs produced by the economy divided by an index of the inputs used by the economy. We regard TFP as a more accurate measure of productivity because labour productivity can increase if the capital input increases dramatically at the same time as TFP is falling.[2]

In the second part of the chapter, we will review a number of Industry Canada studies that bear on the relative productivity performance of the U.S. and Canadian economies. In the section entitled *Trends in Canadian and U.S. Productivity, 1962-98*, we review a study by Serge Coulombe (2000) which evaluates the Canadian TFP estimates made by Statistics Canada. In the section entitled *The Sources of Real Output Growth in Canada*, we present a decomposition of real GDP growth into its primary contributing factors. In the section entitled *The Determinants of Canadian Productivity Growth*, we consider a study by

Richard Harris (1999) which reviews current theories about the determinants of productivity growth. In the section entitled *The Comparison of TFP Growth Rates for U.S. and Canadian Industries*, we consider a study by Wulong Gu and Mun Ho (2000) which looks at total factor productivity growth in 33 U.S. and Canadian industrial sectors over the period 1961-95 based on a common methodology. The authors do not attempt to compare directly the productivity of a Canadian sector with its U.S. counterpart at a point in time; they simply compare the productivity growth rate of the Canadian industry with that of the corresponding U.S. industry. However, another study by Frank Lee and Jianmin Tang (2000) does attempt to compare absolute productivity levels between 33 U.S. and Canadian industries. We discuss this study in the section entitled *The Comparison of TFP Levels for U.S. and Canadian Industries*. Finally, in the last section, entitled *The Canada-U.S. Productivity Gap in Manufacturing Industries*, we discuss a study by Serge Nadeau and Someshwar Rao (2002) which compares the growth rates of labour productivity in Canadian and U.S. manufacturing industries and looks at factors that might explain the productivity gap between the two countries.

TRENDS IN CANADIAN AND U.S. PRODUCTIVITY, 1962-98

IN THIS SECTION, we compare Canadian and U.S. labour productivity and total factor (or multifactor) productivity over the period 1962-98.

For the U.S. economy, the two productivity series are readily available from the Bureau of Labor Statistics (2000) website. For the Canadian economy, Coulombe (2000) has shown that official Statistics Canada estimates of total factor productivity are not comparable with the corresponding U.S. estimates, for three reasons:

- U.S. estimates of labour input are based on a detailed demographic model of labour supply, whereas Canadian estimates of the aggregate labour input are based on an aggregate of industry labour inputs;
- Statistics Canada estimates of multifactor productivity (MFP) do not include the contributions of land and inventories as inputs to the production process, whereas U.S. estimates include these contributions; and
- Statistics Canada depreciation rates for the components of reproducible capital are considerably higher than corresponding U.S. rates, leading to a *slower* growth of the aggregate input and a *faster* growth of total factor productivity in Canada than in the United States.

The third factor is the most important source of methodological difference between the U.S. and Canadian statistical agencies.[3] It is not clear who is correct (on the magnitude of depreciation rates in the United States and Canada), but it seems likely that the actual depreciation rates are not that different.

The difference in assumed depreciation rates between the United States and Canada is very large, as Coulombe (2000) notes:

> For the capital concept that excludes land and inventories, the aggregate implicit depreciation rate in the U.S. averages 4.4 percent between 1961 and 1997. This compares with the depreciation rate of 10 percent used to estimate the growth of Canada's business sector capital stock for MFP measurements. This is a big difference, to say the least. Such a difference in aggregate depreciation rates might be expected to have a large impact on the growth of capital stock and important implications for the measurement of MFP growth. (p. 11)

In an attempt to make the Canadian estimates of total factor productivity growth more comparable to U.S. estimates, we will assume that investment in non-residential structures in Canada depreciates at a declining-balance (geometric) rate of 3.5 percent, and that machinery and equipment investment depreciates at a declining-balance rate of 12.5 percent. This will yield an average depreciation rate for reproducible capital in Canada somewhat higher than the corresponding U.S. rate, but the rates will be much more comparable.

Including land and inventories as productive inputs will tend to *reduce* the rate of growth of the aggregate capital input, and thus the Statistics Canada estimate of capital growth will tend to be *larger* than the corresponding U.S. estimate. Hence, Canadian estimates of total factor productivity growth will tend to be *smaller* than the corresponding U.S. estimates due to the exclusion of these productive inputs in Canada. Coulombe (2000) estimates the magnitude of this exclusion:[4]

> By comparison to the U.S. approach, Statistics Canada's methodology imparts an upward bias to the measurement of capital stock growth and a downward bias to the calculation of MFP growth. We estimate that the effect of using a narrower definition rather than a broader concept of capital stock is to reduce the MFP growth rate by one-tenth of 1 percentage point per year over the 1961-97 period. While this is a small number, MFP annual growth rates are also modest, typically around 1 percent. Consequently, the underestimation amounts to approximately 10 percent of total annual MFP growth. (pp. 9-10)

Thus, putting aside the difference in labour input measures between the United States and Canada,[5] Coulombe estimates that Canadian multifactor productivity estimates are around 0.25 percentage points per year *higher* than the corresponding U.S. estimates over the period 1961-97 due to differences in the definition of the capital input and in the assumed depreciation rates for the components of reproducible capital in the two countries.

Coulombe builds his estimates of Canadian MFP using estimates of industry output. However, estimates of industry output and intermediate inputs are rather fragile in all countries because of a lack of surveys on *intermediate input flows* and, in particular, on *service flows* between industries. Hence, Diewert and Lawrence (2000) estimate Canadian multifactor productivity growth using estimates of *final demand* (adjusted for commodity taxes), which they consider more reliable. In this section, we will update their MFP estimates from 1996 to 1998. One problem with Diewert and Lawrence's estimates is that they are based on Statistics Canada depreciation rates for the components of reproducible capital in Canada. As already mentioned, in this study we use depreciation rates that are closer to the U.S. rates.[6] For a description of our data sources and methodology, see Diewert and Lawrence (2000). For a listing of the major output and input series, see the Appendix at the end of this chapter.[7]

Table 1 shows labour productivity for Canada (LP_{CAN}) and for the United States (LP_{US}) over the period 1962-98. These series represent estimates of private sector gross domestic product divided by a measure of the private business sector labour input.[8] Table 1 also lists estimates of total factor productivity for Canada (TFP_{CAN}) and for the United States (TFP_{US}) over the same period. These series represent estimates of private sector gross domestic product divided by a measure of the private business sector labour input and capital input. The U.S. series are taken from the Bureau of Labor Statistics (2000) website.

The productivity series are graphed in Figure 1. The top line represents U.S. labour productivity, the next line below is Canadian labour productivity, the following line is U.S. total factor productivity, and the bottom line is Canadian total factor productivity.[9] It can be seen that over the 37-year period, the United States had better productivity performance than Canada for both types of productivity. However, the largest TFP gap is not that wide: at the end of the period, U.S. TFP growth only exceeded Canadian TFP growth by about 7.5 percent, while U.S. labour productivity growth exceeded Canadian labour productivity growth by about 19.5 percent.

It is useful to break down the productivity growth performance of the two countries into various sub-periods. The first sub-period covers the years 1963 to 1973 (11 years). This partly coincides with the *golden* years of productivity growth in both countries. The next sub-period spans the *dismal* years, that is 1974 to 1991 (18 years). These were the years of the two energy shocks (1974 and 1979-80), of high inflation,[10] and of a worldwide recession (around 1991).

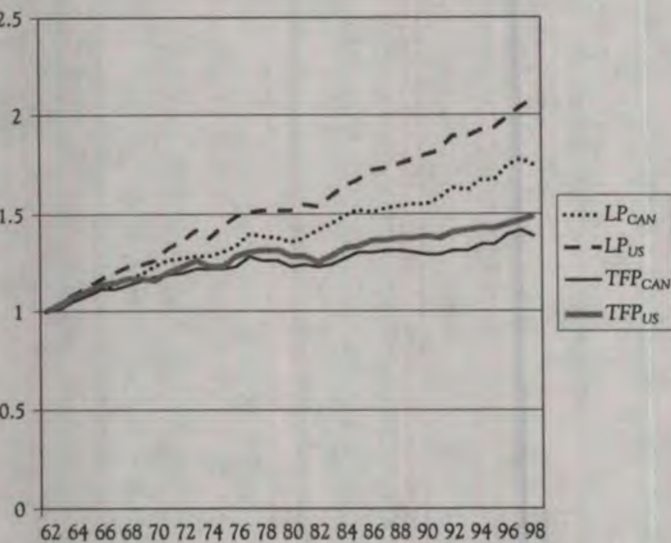
TABLE 1

ESTIMATES OF LABOUR PRODUCTIVITY AND TOTAL FACTOR PRODUCTIVITY, CANADA AND THE UNITED STATES, 1962-98

YEAR	LP_{CAN}	LP_{US}	TFP_{CAN}	TFP_{US}
1962	1.0000	1.0000	1.0000	1.0000
1963	1.0200	1.0397	1.0174	1.0305
1964	1.0544	1.0870	1.0542	1.0712
1965	1.0852	1.1267	1.0840	1.1061
1966	1.1189	1.1720	1.1118	1.1395
1967	1.1337	1.1985	1.1127	1.1410
1968	1.1674	1.2363	1.1336	1.1701
1969	1.1913	1.2420	1.1505	1.1657
1970	1.2326	1.2665	1.1747	1.1628
1971	1.2605	1.3214	1.1931	1.2006
1972	1.2727	1.3648	1.2020	1.2355
1973	1.2858	1.4083	1.2207	1.2689
1974	1.2840	1.3837	1.2152	1.2224
1975	1.2994	1.4329	1.2153	1.2326
1976	1.3285	1.4839	1.2344	1.2805
1977	1.3970	1.5085	1.2800	1.3009
1978	1.3845	1.5255	1.2663	1.3169
1979	1.3805	1.5255	1.2607	1.3125
1980	1.3591	1.5198	1.2305	1.2834
1981	1.3818	1.5501	1.2386	1.2863
1982	1.4220	1.5444	1.2265	1.2471
1983	1.4558	1.5992	1.2428	1.2834
1984	1.4897	1.6446	1.2751	1.3256
1985	1.5158	1.6767	1.2975	1.3401
1986	1.5122	1.7278	1.2947	1.3619
1987	1.5364	1.7372	1.3149	1.3663
1988	1.5385	1.7580	1.3155	1.3750
1989	1.5466	1.7750	1.3093	1.3837
1990	1.5470	1.7996	1.2916	1.3852
1991	1.5793	1.8204	1.2913	1.3721
1992	1.6303	1.8904	1.3178	1.4041
1993	1.6268	1.8998	1.3111	1.4113
1994	1.6694	1.9263	1.3511	1.4259
1995	1.6685	1.9395	1.3497	1.4302
1996	1.7417	1.9924	1.3990	1.4535
1997	1.7837	2.0340	1.4228	1.4695
1998	1.7477	2.0888	1.3856	1.4913

FIGURE 1

LABOUR PRODUCTIVITY AND TOTAL FACTOR PRODUCTIVITY, CANADA AND THE UNITED STATES, 1962-98*



Note: * Base year 1962=1.00.

Our final sub-period covers the years 1992-98 (7 years), during which inflation subsided and there were no major recessions. Productivity growth rates are calculated from the data presented in Table 1, by dividing each year's level by the previous year's level. The annual productivity growth rates are then averaged over the sub-periods described above. The results are reported in Table 2.

In Table 2, we can see that over the entire 37-year period, labour productivity in the United States exceeded that of Canada by 0.5 percentage points per year on average. For the more important total factor productivity measure, U.S. TFP growth exceeded that of Canada by about 0.2 percentage points per year. In *absolute* terms, this does not seem like a large productivity gap, but given that the average TFP growth rate in both countries is only about 1 percent per year, this translates into a 20 percent *relative* gap. It is apparent that the golden era of productivity growth was indeed very good for both countries during the period prior to the first oil shock, near the end of 1973, averaging about 2 percent per year in both countries. However, during the high-inflation

TABLE 2

AVERAGE CANADIAN AND U.S. PRODUCTIVITY GROWTH RATES, 1963-98

PERIOD	GLP_{CAN}	GLP_{US}	$GTFP_{CAN}$	$GTFP_{US}$
		(PERCENT)		
1963-98	1.58	2.08	0.92	1.13
1963-73	2.32	3.17	1.83	2.20
1974-91	1.16	1.45	0.32	0.45
1992-98	1.48	1.99	1.03	1.20

period of 1974-91, this high rate of TFP growth fell dramatically in both countries: to 0.32 percent per year in Canada, and to 0.45 percent per year in the United States. Finally, in the *new economy* era of the 1990s (1992-98), TFP growth picked up in both countries, increasing to about 1.0 percent per year in Canada and to 1.2 percent in the United States. However, these growth rates are still below the TFP growth rates achieved in the pre-1973 period.[11] Note that for all time periods, the United States appears to have had faster rates of productivity growth than Canada.

We now turn to an analysis of the relative contribution of TFP growth to the growth of real output in Canada.

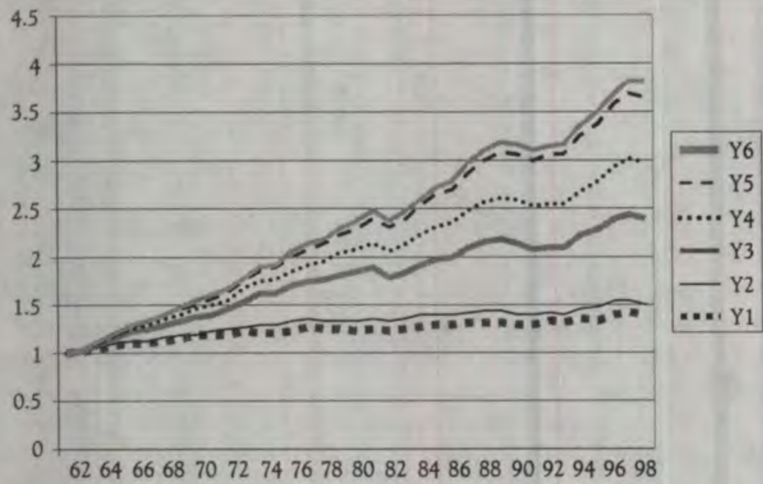
THE SOURCES OF REAL OUTPUT GROWTH IN CANADA

KOHLI (1990) DEVELOPED a very illuminating decomposition of a country's nominal GDP growth into various explanatory factors, such as the increase in the country's domestic prices and its export and import prices, and the growth of its primary inputs like labour and capital.[12] An explanation of Kohli's methodology is provided in the Appendix to this chapter.

The top line in Figure 2 (labelled Y6) represents real GDP growth in Canada over the years 1962-98. The bottom line (Y1) represents the contribution of TFP growth. The next line up (Y2) represents the additional contribution of changes in the terms of trade. It can be seen that this contribution is much smaller than the effects of productivity growth. The next line (Y3) represents the additional contribution of labour input growth to real output growth. It can be seen that, of all the sources of growth, this is the biggest contributor. Next comes the contribution of increases in the stock of non-residential structures (Y4), which is approximately equal to the contribution of increases in TFP. Then comes the contribution of increases in the stock of machinery and equipment (Y5), which is also approximately equal to the contribution of TFP growth. The top line (Y6) adds the contribution of growth in inventories, which is rather small. Figure 2 shows at a glance that the main drivers of real

FIGURE 2

DECOMPOSITION OF OUTPUT INTO EXPLANATORY FACTORS, 1962-98*



Note: *Base year: 1962 = 1.00.

output growth in Canada over the past 37 years have been *labour input growth and capital input growth*. Unfortunately, growth in TFP has not been a very large contributor to overall output growth in Canada.

The analysis does not tell us what the determinants of Canadian TFP growth were; it just tells us that over the past 25 years or so, TFP growth does not appear to have been very substantial. In the next section, we review a study by Harris (1999) which attempts to map out the factors that influence TFP growth.

THE DETERMINANTS OF CANADIAN PRODUCTIVITY GROWTH

RICHARD HARRIS (1999) IDENTIFIES three main drivers of productivity growth: i) investments in machinery and equipment, ii) investments in education, training and human capital development, and iii) openness of the economy to international trade and foreign direct investment.

These three drivers seem very reasonable. New knowledge is often embodied in new machines, so old tasks can be performed more efficiently. Educating workers enables them to accomplish a wide variety of tasks more efficiently.

An economy with high tariffs and import quotas will often have many other distortions that prevent prices from allocating resources efficiently. In theory, these efficiency losses induced by tariffs and taxes only affect the level of output and consumption, but not productivity growth *per se*. In practice, however, a highly distorted economy will usually not be attractive for undertaking research and development, or for investing in new plant and equipment. Hence, productivity growth can suffer.

Harris (1999, pp. 15-16) also looks at a broader set of factors that might influence productivity growth. Here are some of the factors he lists that we consider highly plausible:

- Innovation. The development of new products or processes somewhere in the world for the first time.
- Diffusion of innovation. The adoption of a new product or process in the local economy.
- Economies of scale. Many physical processes are more efficient when exploited at a larger scale. Put another way, commodities are lumpy or at least sold in discrete lumps. We simply cannot buy very tiny amounts of most commodities. Put yet another way, the economy is filled with fixed costs. There are fixed costs in developing a new product, there are fixed costs in selling a commodity, there are fixed costs in transporting commodities, etc. As market scale increases, these fixed costs shrink as a proportion of the selling price and economic efficiency improves.[13]
- Spatial agglomeration, or the growth of cities. Large cities allow specialized markets to develop both on the product side and on the skill side. On the other hand, in rural communities, the number of goods and services that can be purchased locally is limited[14] and producers may not be able to find the specialized workers they require. This point is related to the previous one: as cities grow, markets become larger and a greater specialization of labour is possible.[15]
- The provision of public infrastructure for transport, communication and waste removal. This factor becomes very important when it is absent!
- Management practices. This explanatory factor could perhaps be subsumed under the diffusion of technology heading, but we concur with Harris in giving it a separate billing. In particular, the contribution of business consultants who bring information on global best practices to the local economy offer a relatively inexpensive way of increasing productivity dramatically.[16]

- High taxes (negative). Unless the revenues raised by high taxes are spent incredibly well, there will be deadweight losses and marginal excess burdens associated with heavy tax regimes. Again, this would seem to be a *level* effect that does not necessarily affect TFP growth. However, in a world where some governments offer lower tax rates than others, economic activity and foreign investment will be attracted to low-tax locations and this, in turn, will stimulate TFP growth given the link between investment and TFP growth. Conversely, footloose investments will avoid high-tax jurisdictions and, as a result, TFP growth will suffer.[17]
- Small firms (negative). Small firms cannot afford large investments in research and development, they may not be able to specialize adequately and they may have large fixed costs. In general, very small firms will not be as efficient as large firms. In spite of this, governments tend to favour small firms and penalize large firms in all sorts of ways.[18]
- Labour market flexibility (positive). This factor fits in with the second main driver of productivity growth identified by Harris. Recent reforms to the Canadian unemployment insurance system[19] very modestly penalize repeat users of what is now called employment insurance. These reforms were necessary to remove from the old unemployment insurance system the very hefty subsidy going to seasonal workers, and create a system that provides temporary relief to workers who (permanently) lose their jobs. However, it is proving difficult for governments to live with the new regime even though it improves labour market flexibility.
- Low inflation (positive). It seems difficult to make the case that this factor greatly influences productivity growth. But looking at the recent economic history of OECD countries, we are struck by the empirical fact that virtually every country experienced a dramatic drop in TFP growth during the years 1974-91 and, simultaneously, a big increase in inflation. Diewert and Fox (1999) identify a couple of mechanisms through which higher inflation might have translated into lower rates of TFP growth: i) business income-tax systems were not generally indexed for the effects of inflation, and businesses that used capital inputs with low depreciation rates were thus unfairly penalized, and ii) multi-product businesses probably did not price their products correctly in periods of high inflation. The debate on this topic is still open but we seem to witness a resurgence of TFP growth in recent years as inflation remains low in most OECD countries.

The above discussion will probably suffice to give the flavour of Harris' work on productivity. As can be seen from our comments, we generally agree with his review. Basically, we have a fairly good idea of what factors influence productivity growth, but firm evidence on most of these factors is still lacking.

We now turn to a discussion of some of the other studies in the Industry Canada research program on productivity.

THE COMPARISON OF TFP GROWTH RATES FOR U.S. AND CANADIAN INDUSTRIES

GU AND HO (2000) COMPARE THE TFP GROWTH of 33 Canadian and U.S. industries that encompass the private business sector in both countries (in a comparable fashion) over the period 1961-95. Basically, they take a bottom-up approach to TFP comparisons between the two countries, whereas in the second section above we took a top-down approach. In other words, Gu and Ho use detailed industry data for both countries in their industry-by-industry comparisons, whereas we just use final demand data. However, both methods seem to yield the same conclusion: in the period up to 1973, Canadian industries were able to bring their productivity levels closer to U.S. levels, but after 1973 productivity growth slowed down in both countries and Canadian firms were unable to close the productivity gap after 1973. Gu and Ho's approach gives a great deal of additional information on the industries that had above-average TFP growth rates in the two countries.[20]

It should be stressed that Gu and Ho use an identical methodology in both countries so that like is compared to like. These authors are to be commended for their development of new demographic-type industry labour input series for Canada so that Canadian labour data is comparable with U.S. data.

It should be noted that Gu and Ho use a gross output or KLEM (capital, labour, energy and materials) approach to the measurement of TFP — labour, capital and intermediate factors are regarded as inputs into an industry production function that produces the industry gross output. When they aggregate their industry data to obtain an overall business sector estimate of TFP in both countries, they do not net out inter-industry intermediate input deliveries. Thus, their estimates of business sector TFP growth should automatically be *smaller* than the estimates of TFP growth listed above in the section entitled *Trends in Canadian and U.S. Productivity, 1962-98*, which are based on a superlative index double-deflation method of output formation; i.e., real value-added measures of output were used.[21] Now there is absolutely nothing wrong with Gu and Ho's method, but it is necessary to keep in mind that it will generate smaller measures of TFP growth than the value-added measure.[22]

Our overall evaluation of Gu and Ho's study is that it is certainly the best attempt at comparing TFP industry growth rates across Canadian and U.S. industries to date. We particularly like their new estimates of labour input by industry for Canada. We are not quite as positive on their measures of capital input, but they certainly achieved comparability across Canadian and U.S. industries.[23]

Gu and Ho's work plays an important role in the study examined below.

The Comparison of TFP Levels for U.S. and Canadian Industries

Lee and Tang (2000) take the productivity growth rate comparisons between Canadian and U.S. industries presented in the previous section one step further. They undertake a purchasing-power-parity exercise for the year 1992 and are then able to compare the absolute level of productivity of a Canadian industry with its U.S. counterpart. The details of their calculations are given in their study and will not be reviewed here. Suffice it to say that we think that they did a very good job.

Once they have common quantity units in the United States and Canada, by industry, for the year 1992, Lee and Tang can use the growth rates for inputs and outputs calculated by Gu and Ho (2000) and estimate comparable TFP levels for the same U.S. and Canadian industry over the period 1961 to 1995. Lee and Tang find that in 1995, 29 out of 33 Canadian industries had lower TFP levels than their U.S. counterparts.

Our only reservation about this study is the use of Jorgenson and Kuroda's measure of competitiveness, defined as the ratio of gross output prices in the two industries being compared. We do not consider this a very compelling index of competitiveness, and we think that the relative TFP level is a much more satisfactory index. If an American firm is producing, say, 20 percent more output per unit of input than a Canadian firm in the same industry, then we would say that the American firm has a pretty good competitive advantage!

We turn now to the final study in our review.

The Canada-U.S. Productivity Gap in Manufacturing Industries

The final study reviewed, by Nadeau and Rao (2002), also looks at U.S. and Canadian relative productivity levels but uses labour productivity[24] instead of total factor productivity (the comparisons are mostly made for manufacturing industries). This study, like that of Harris discussed earlier, also tries to explain why Canada is not performing as well as the United States.

The picture painted by Nadeau and Rao is consistent with that given by the previous authors: there is a labour productivity gap between the United States and Canada and it seems to be widening over time. The gap appears to be widening more rapidly in manufacturing than in the business sector as a whole (see Figure 6 in Nadeau and Rao, 2002). In 1996, there were only three Canadian industries with a substantial labour productivity advantage over their American counterparts: Primary Metals, Paper and Allied Products, and Lumber and Wood Products.

Turning now to the explanations for the poor Canadian performance, Nadeau and Rao point out that Canada seems to have been less successful in shifting resources (in manufacturing) towards activities with higher productivity growth than the United States. Of course, the next question is: Why? One factor mentioned by the authors is that Canada's venture capital market is not as well developed as in the United States. However, Nadeau and Rao feel that the key explanatory factor is Canada's failure to adequately transform itself into a knowledge-based economy. They document the facts that the share of R&D expenditures in Canadian manufacturing is much less than the corresponding U.S. share, and that Canadian firms lag behind U.S. firms in adopting new technologies. The share of machinery and equipment investment in Canada's GDP was 35 percent below that of the United States in 1998. Finally, Nadeau and Rao point out that there are relatively more small firms in Canada than in the United States and, of course, small firms cannot achieve much economies of scale, they do relatively less R&D, and are simply not as productive as large firms.

All of the above is true, but we must admit to still feel a bit puzzled as to why Canada has not shared more substantially in the recent U.S. productivity boom. The poorest U.S. state is Mississippi and, according to the Bureau of Economic Analysis, it achieved a per capita income of US$20,688 in 1999. This translates into a fairly good per capita income in Canadian dollars.[25] Moreover, in August 2000, according to the Bureau of Labor Statistics, Mississippi's unemployment rate fell below 5 percent (to 4.9 percent) for the first time in years. Given that we have a free-trade agreement with the United States, why are Canadian provinces not sharing in the general U.S. prosperity to the same extent? If unemployment rates can equalize at low levels across all regions of the United States, why not in Canada?

It seems that two major factors not discussed by Nadeau and Rao might help to explain why Canadians are not sharing fully in the integrated North American market:

- Canadian tax rates are by and large much higher than those in the United States; and

- Canadian employment insurance is much more generous than in the United States, and this discourages labour mobility and prevents the equalization of provincial unemployment rates.

Not all economists agree that high taxes play much of a role in explaining productivity growth, but we would like to mention Ireland as an example of a low (business) tax jurisdiction that has succeeded in attracting a tremendous inflow of foreign investment and British Columbia as an example of a high-tax jurisdiction that has managed to choke off the flow of inward investment. Both Harris' study and Nadeau and Rao's study note the close connection of investment in machinery and equipment with productivity growth.

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THE AUTHOR WOULD LIKE TO CONCLUDE by commending Industry Canada for funding and stimulating a great deal of very useful research on productivity.

ENDNOTES

1 However, we will not actually compare the level of output in Canada with that of the United States. This is done in Lee and Tang (2002).

2 In practice, labour productivity and total factor productivity usually move in the same direction.

3 Coulombe (2000, p. 11) notes that "by applying BEA depreciation procedures, Canada's capital stock since 1980 increases by about one percent per year." Thus, by applying U.S. depreciation rates, official Canadian multifactor productivity growth is reduced by about 0.3-0.35 percentage points per year over the last 20 years or so.

4 Coulombe (2000, p. 22) notes that: "Diewert and Lawrence (2000), from a completely different methodology and using Canadian data only, arrive at exactly the same number. They estimate that the exclusion of land and inventories as inputs decreases multifactor productivity growth in Canada by 0.1 percent per year."

5 Gu and Ho (2000) construct a Canadian labour input series that is a counterpart to that used by the Bureau of Labor Statistics (BLS) in the United States.

6 There are other differences in the data used in this study compared to Diewert and Lawrence (2000): i) revised Statistics Canada data were used; ii) in this study, data on investment going back to 1926 come from Leacy (1983) (see series F19, F20, F43 and F44) and are used for the years 1926-61; and, iii) in order to obtain starting capital stocks for non-residential structures and for machinery and equipment in 1926, it was assumed that gross fixed capital formation in these components

was growing at a 2-percent annual rate in the years prior to 1926 and that the declining-balance depreciation rate for non-residential structures was 3.5 percent per year and, for machinery and equipment, 12.5 percent per year. These assumptions gave us starting capital stocks that were roughly equal to the starting stocks listed in Leacy (1983) for 1926.

7 The output series listed in the Appendix were built up from 34 detailed output series on 20 consumption components, one government component, five investment components, five export components and four import components, covering the years 1962-98. Fisher ideal chain indexes were used to aggregate these detailed series into the usual national-accounts-type aggregates (but at producer prices rather than final demand prices). Statistics Canada data were used throughout the data construction process.

8 The labour productivity series have been normalized to equal unity in 1962. The total factor productivity series do not have to be normalized because the value of input is equal to the value of output in each period.

9 In the following section, we indicate more precisely how our estimate of Canadian TFP was constructed.

10 Diewert and Fox (1999) argue that high inflation will tend to reduce productivity growth for a variety of reasons.

11 Griliches (1979) and Diewert and Fox (1998) argue that current real output is surely higher than measured by statistical agencies due to the lack of quality adjustment in the measurement of services. Since the service sector has been growing steadily since the golden years of productivity growth, it is likely that current TFP is higher than currently measured.

12 Kohli's work draws on Diewert and Morrison (1986). See, also, Fox and Kohli (1998) for a recent application of this methodology to Australia.

13 Alfred Marshall (1898, chapter 11, p. 358) is quite good on this point: "Again, it is true that when a hundred sets of furniture or clothing, have to be cut out on exactly the same pattern, it is worthwhile to spend great care on so planning the cutting out of the boards or the cloth, that only a few small pieces are wasted."

14 Of course, this situation is rapidly changing as far as goods are concerned due to the provision of goods and some services over the Internet.

15 Marshall (1898, p. 396) described his famous external economies of scale as follows: "Meanwhile an increase in the aggregate scale of production of course increases those economies, which do not directly depend on the size of individual houses of business. The most important of these result from the growth of correlated branches of industry which mutually assist one another, perhaps being concentrated in the same localities, but anyhow availing themselves of the modern facilities for communication offered by steam transport, by the telegraph and by the printing press."

16 Harris (1999, p. 19) later makes the following point: "There is a growing body of evidence that the growth process is fundamentally driven by the *relocation of resources from low-productivity growth activities to high-productivity growth activities, rather than by limits on the availability of new technology*." We totally agree on this point. For evidence on the vast differences in productivity among firms using essentially the same technology, see Diewert and Nakamura (1999).

17 Many private-sector economists in British Columbia contrast the high-tax policies of the province with the lower tax policies of Alberta, and attribute to this factor the relative increase in investment in Alberta. Another example is the Irish economy, which has experienced a boom due in part to its low rates of business taxation.

18 In Canada, small firms pay a lower rate of business income tax and they are not subject to many rather onerous programs that governments reserve for large firms.

19 See Nakamura and Diewert (2000).

20 However, there is a downside to making industry-by-industry productivity comparisons: the input-output tables in both countries are not very reliable; hence, there is likely to be a large measurement error in these comparisons. On the other hand, the components of final demand are likely to be measured with much less error.

21 Productivity in the gross-output formulation is $Y/(I+L+K)$, where Y is gross output, I is intermediate input use, L is labour input and K is capital input. Productivity in the real value-added framework is roughly $(Y-I)/(L+K)$. Now suppose there is a productivity improvement of ΔY with all inputs remaining constant. The gross-output productivity growth rate is $[(Y+\Delta Y)/(I+L+K)]/[Y/(I+L+K)] = (Y+\Delta Y)/Y = 1+(\Delta Y/Y)$, which is less than the real value-added productivity growth rate, $[(Y+\Delta Y-I)/(L+K)]/[(Y-I)/(L+K)] = 1+[\Delta Y/(Y-I)]$. Thus, the smaller numerator in the value-added TFP measure translates into larger TFP growth estimates.

22 It is sometimes thought that the theoretical assumptions required to justify the gross-output productivity measure are less restrictive than those required for the value-added measure. However, the theoretical model of Diewert and Morrison (1986) shows that both approaches can be justified based on the same assumptions.

23 Gu and Ho (2000) use Jorgenson's user-cost methodology where: i) industry ex-post rates of return are used as the opportunity cost of capital; and ii) *ex-post* asset capital gains are used as estimates of *ex ante* or anticipated capital gains. Both of these assumptions tend to introduce a fair bit of measurement error and volatility into their user-cost estimates.

24 The authors argue correctly that there are fewer measurement problems in constructing comparable indexes of labour productivity.

25 We are not taking the distribution of income into account here.

26 In our empirical work, q_D^t was defined as a Fisher ideal chain aggregate of 20 separate consumption series plus one government series and four investment series. See Diewert and Lawrence (2000) for a detailed description of these series.

27 In our empirical work, q_X^t is a Fisher ideal chain aggregate of five Canadian export components, and q_M^t is a Fisher chain aggregate of four Canadian import components.

28 These user costs are explained in Diewert and Lawrence (2000) and in the Appendix.

29 Essentially, the technology of the country has to be representable by a certain translog profit function; see Diewert and Morrison (1986) or Kohli (1990) for details. The assumptions do not appear to be very restrictive.

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APPENDIX

THE DECOMPOSITION OF OUTPUT

DEFINE q_D^t AS THE QUANTITY OF DOMESTIC FINAL DEMAND in period t and let p_D^t be the corresponding price.[26] Define q_X^t and q_M^t as the quantity of exports and imports in period t and let p_X^t and p_M^t be the corresponding prices.[27] Then, nominal GDP in period t is defined as:

$$(1) \quad v^t \equiv p_D^t q_D^t + p_X^t q_X^t - p_M^t q_M^t .$$

In Appendix Table A3 below, we list the quantities that appear in Equation (1). The q variables are in billions of 1962 dollars, but v^t is in billions of current dollars.

Looking at the last three columns of Table A3, we can see that both exports and imports have grown much more rapidly than domestic demand in real terms. However, the growth of imports is much faster than the growth of exports. This is due to increasing imports of high-tech equipment from the United States and other areas, which is falling in price. From Table A4 below, it can be verified that export prices are increasing faster than import prices; i.e., the terms of trade for Canada improved over the period 1962-98.

Let's use the above data to construct an implicit (chain) Törnqvist index of outputs, with q_D, q_X and $-q_M$ as the three quantities to be aggregated with price weights p_D, p_X and p_M, respectively. This aggregate output index is to be divided by a Törnqvist index of five inputs and this is the TFP index, say a^t, listed in column 4 of Table 1. The five inputs are: labour, non-residential structure services, machinery and equipment services, inventory services, and business and agricultural land services. Denote the price and quantity of private sector labour input in period t by p_L^t and q_L^t, respectively. Denote the declining balance user costs of the four types of capital input in period t by u_{NS}^t, u_{ME}^t, u_{IS}^t and u_{BAL}^t, respectively.[28] Denote the quantity used of each of these types of capital in period t by q_{NS}^t, q_{ME}^t, q_{IS}^t and q_{BAL}^t. The corresponding data are listed below.

Kohli (1990) shows that v^t, the nominal GDP in period t, has the following decomposition into explanatory factors if certain conditions on the country's technology hold:[29]

$$(2) \quad v^t = v^1\, a^t\, b_D^t\, b_X^t\, b_M^t\, c_L^t\, c_{NR}^t\, c_{ME}^t\, c_{IS}^t\, c_{BAL}^t ,$$

where v^1 is nominal GDP in a base period (period 1), a^t is the Törnqvist TFP index for period t (see column 4 of Table 1), b_D^t, b_X^t and b_M^t are the translog price effects defined in Diewert and Morrison (1986, p. 666), and c_L^t, c_{NR}^t, c_{ME}^t, c_{IS}^t and c_{BAL}^t are the translog quantity effects defined in Diewert and Morrison (1986, p. 667). Each price effect represents the effect on period t nominal GDP due to the change in the price of domestic output going from period $t-1$ to period t (the b_D^t price effect), the price of exports (the b_X^t effect) or the price of imports (the b_M^t effect). Each quantity effect represents the effect on period t nominal GDP due to the change in the quantity of each primary input going from period $t-1$ to period t. The logarithmic change in the *nth* price effect going from period $t-1$ to period t is defined empirically as follows:

(3) $\ln (b_n^t/b_n^{t-1}) \equiv 1/2[s_n^{t-1} + s_n^t] \ln (p_n^t/p_n^{t-1})$; $n = D, X$ or M.

The period t expenditure share for (net) output n is defined as:

(4) $s_D^t \equiv p_D^t q_D^t / v^t$; $s_X^t \equiv p_X^t q_X^t/v^t$, and $s_M^t \equiv -p_M^t q_M^t/v^t$.

The logarithmic change in the *nth* quantity effect going from period $t-1$ to period t is defined empirically as follows:

(5) $\ln (c_n^t/c_n^{t-1}) \equiv 1/2[\sigma_n^{t-1} + \sigma_n^t] \ln (q_n^t/q_n^{t-1})$; $n = L, NR, ME, IS$ and BAL,

where the period t expenditure share for primary input n is defined as:

(6) $\sigma_L^t \equiv p_L^t q_L^t/v^t$; $\sigma_{NR}^t \equiv u_{NR}^t q_{NR}^t/v^t$; $\sigma_{ME}^t \equiv u_{ME}^t q_{ME}^t/v^t$; $\sigma_{IS}^t \equiv u_{IS}^t q_{IS}^t/v^t$

and $\sigma_{BAL}^t \equiv u_{BAL}^t q_{BAL}^t/v^t$.

Definitions (4) and (6) along with period 1 normalizations for $b_n^1 = 1$ and $c_n^1 = 1$ serve to define b_n^t and c_n^t for all periods $t = 1,2,\ldots,37$. Since we assume that the quantity of business and agricultural land is fixed, the quantity effect c_{BAL}^t is always equal to 1 and, hence, can be ignored in the decomposition (2). The remaining price and quantity effects are listed in Table A5 below.

Looking at Table A5, it can be seen that the smallest effects on GDP growth come from the accumulation of inventories. The largest effects on nominal GDP growth come from changes in domestic prices (due to inflation). Comparing entries in Tables A4 and A5, it can be seen that the domestic price effect series, b_D^t, is virtually identical to the domestic inflation price series, p_D^t.

As mentioned above, because the quantity of business and agricultural land is assumed constant in our study, the quantity effect c_{BAL}^t is identically equal to unity. Hence, we can rewrite the decomposition of nominal GDP given by Equation (2) above as follows:

(7) $(v^t/v^1)/b_D{}^t = a^t\, b_X{}^t\, b_M{}^t\, c_L{}^t\, c_{NR}{}^t\, c_{ME}{}^t\, c_{IS}{}^t = a^t\, b_T{}^t\, c_L{}^t\, c_{NR}{}^t\, c_{ME}{}^t\, c_{IS}{}^t$.

As mentioned above, $b_D{}^t$ is essentially equal to the price of domestic output, $p_D{}^t$. Hence, the left-hand side of Equation (7) is essentially real GDP (normalized to equal 1 in the base period). On the right-hand side, we have a series of factors that contribute to real growth; namely: TFP growth a^t, $b_T{}^t \equiv b_X{}^t\, b_M{}^t$, which is the combined effect of changes in export and import prices or changes in the terms of trade, labour growth $c_L{}^t$, the growth of non-residential structures, $c_{NR}{}^t$, the growth in the use of machinery, $c_{ME}{}^t$, and the growth in inventory stocks, $c_{IS}{}^t$. In Table A6 below, we start with TFP growth (a^t) as a contributor to real output growth; then, in the second column, we table the combined effects of TFP growth and changes in the terms of trade ($a^t\, b_T{}^t$). In the third column, we add the effects of labour input growth; in the fourth column, we add the effects of growth in the stock of non-residential structures; in the fifth column, we add the effects of growth in machinery and equipment stocks; and in the sixth column, we add in the effects of inventory growth. The seventh column is $(v^t/v^1)/b_D{}^t$, the normalized deflated GDP, which is indeed exactly equal to the sixth column. Figure 2 graphically depicts these columns.

DATA

TABLE A1

CANADIAN BUSINESS SECTOR PRIMARY INPUT QUANTITIES, 1962-98 (1962$ MILLIONS)

YEAR	q_L^t	q_{NS}^t	q_{ME}^t	q_{IS}^t	q_{BAL}^t
1962	24,181.5	4,775.9	3,697.4	1,435.2	1,387.2
1963	24,720.8	4,991.4	3,746.5	1,517.5	1,387.2
1964	25,662.3	5,212.5	3,833.2	1,566.0	1,387.2
1965	26,624.7	5,487.6	4,006.9	1,614.0	1,387.2
1966	27,600.0	5,794.6	4,272.9	1,733.0	1,387.2
1967	28,243.0	6,164.5	4,652.1	1,855.2	1,387.2
1968	28,635.5	6,491.7	5,003.8	1,891.9	1,387.2
1969	29,294.8	6,802.9	5,246.9	1,970.7	1,387.2
1970	29,388.4	7,103.8	5,542.0	2,134.9	1,387.2
1971	29,859.1	7,446.5	5,818.5	2,174.0	1,387.2
1972	30,731.1	7,795.8	6,089.5	2,206.8	1,387.2
1973	32,376.2	8,130.4	6,407.8	2,219.3	1,387.2
1974	33,504.9	8,501.2	6,928.1	2,263.9	1,387.2
1975	34,018.2	8,899.2	7,550.4	2,424.5	1,387.2
1976	35,004.5	9,374.3	8,179.7	2,492.1	1,387.2
1977	35,146.0	9,814.6	8,799.0	2,653.5	1,387.2
1978	36,609.0	10,285.9	9,336.9	2,864.9	1,387.2
1979	38,016.9	10,761.9	9,942.0	2,975.0	1,387.2
1980	38,925.1	11,328.8	10,761.4	3,124.2	1,387.2
1981	39,634.4	11,983.3	11,905.3	3,029.9	1,387.2
1982	37,414.8	12,695.0	13,426.3	3,076.7	1,387.2
1983	37,379.0	13,278.8	14,285.3	2,819.3	1,387.2
1984	38,731.0	13,757.3	14,989.5	2,749.7	1,387.2
1985	40,039.2	14,209.0	15,773.1	2,898.1	1,387.2
1986	41,542.2	14,691.9	16,862.1	2,980.3	1,387.2
1987	42,950.8	15,101.2	18,147.2	3,039.6	1,387.2
1988	44,532.9	15,531.9	19,794.7	3,136.1	1,387.2
1989	45,185.4	16,044.9	21,965.4	3,208.8	1,387.2
1990	45,241.8	16,572.4	24,222.6	3,331.5	1,387.2
1991	43,573.2	17,084.0	25,975.6	3,272.4	1,387.2
1992	43,086.4	17,542.3	27,535.3	3,208.7	1,387.2
1993	43,694.3	17,819.8	29,024.3	3,241.0	1,387.2
1994	45,115.4	18,092.3	30,098.3	3,204.8	1,387.2
1995	46,193.0	18,435.1	31,483.3	3,323.7	1,387.2
1996	46,497.8	18,771.9	33,198.3	3,477.3	1,387.2
1997	47,198.7	19,144.9	35,219.4	3,919.9	1,387.2
1998	48,672.2	19,649.6	38,358.0	4,552.6	1,387.2

TABLE A2

CANADIAN BUSINESS SECTOR PRIMARY INPUT PRICES, 1962-98

YEAR	p_L^t	u_{NS}^t	u_{ME}^t	u_{IS}^t	u_{BAL}^t
1962	1.0000	1.0000	1.0000	1.0000	1.0000
1963	1.0487	1.0315	1.0293	1.0278	1.0736
1964	1.0926	1.1231	1.0879	1.1574	1.2591
1965	1.1696	1.2081	1.1240	1.2298	1.4532
1966	1.2782	1.2836	1.1627	1.2952	1.6126
1967	1.3520	1.2997	1.1504	1.2829	1.7425
1968	1.4494	1.3217	1.1799	1.3458	1.9382
1969	1.5774	1.3647	1.1611	1.3052	2.0514
1970	1.6913	1.4164	1.2126	1.3414	2.2169
1971	1.8196	1.4714	1.2319	1.3705	2.3730
1972	1.9701	1.5046	1.2528	1.3920	2.6199
1973	2.1759	1.7656	1.3334	1.6927	3.3559
1974	2.4907	2.0939	1.4786	1.9842	4.2088
1975	2.8371	2.2153	1.6596	2.0714	4.9576
1976	3.1596	2.3669	1.7573	2.2279	6.0214
1977	3.4634	2.5413	1.8829	2.3971	7.1191
1978	3.6332	2.6820	1.9442	2.4773	8.0499
1979	3.9337	3.0112	2.1250	2.8227	9.7144
1980	4.3311	3.3275	2.0019	2.9030	11.4043
1981	4.8726	3.7084	2.0287	3.1358	13.7576
1982	5.4888	3.5265	2.0257	2.7714	12.6700
1983	5.7968	3.7921	2.0956	3.1332	13.9276
1984	6.0582	4.1787	2.1293	3.4828	14.9210
1985	6.3573	4.3463	2.0878	3.5672	15.2854
1986	6.5659	4.2689	2.0285	3.5161	14.2134
1987	6.8835	4.7906	2.0746	4.0683	16.4086
1988	7.3165	4.8785	1.9945	4.0090	16.8668
1989	7.7354	4.9978	2.0271	4.0583	17.8156
1990	8.0825	4.6283	1.8731	3.4699	17.0501
1991	8.6122	4.2198	1.7111	3.0468	15.7859
1992	8.9155	4.2361	1.6692	3.0568	16.8677
1993	9.0162	4.2608	1.7007	3.0971	17.3264
1994	8.9908	5.0348	1.9009	3.8979	21.1909
1995	9.1340	5.2316	1.9228	4.0675	22.8880
1996	9.3609	5.9060	2.0052	4.7764	27.4722
1997	9.7970	5.8170	1.9608	4.5428	27.8066
1998	9.9363	5.1467	1.7598	3.6512	23.8580

TABLE A3

CANADIAN QUANTITY COMPONENTS OF NOMINAL GDP, 1962-98

YEAR	v^t	q_D^t	q_X^t	q_M^t
1962	35,477.2	36,276.9	7,458.8	8,258.5
1963	37,926.3	37,461.8	8,220.5	8,683.2
1964	41,678.2	40,146.8	9,419.6	9,869.8
1965	46,349.1	43,651.5	9,700.8	11,006.3
1966	52,196.2	46,790.6	11,079.2	12,657.7
1967	56,267.5	48,016.2	12,046.1	13,161.5
1968	61,087.1	50,030.1	13,515.1	14,640.7
1969	66,898.5	53,031.8	14,396.0	16,536.6
1970	72,220.9	53,333.0	15,964.3	16,266.1
1971	78,391.6	56,299.3	16,031.7	17,349.8
1972	86,188.6	59,383.2	17,358.2	19,887.7
1973	101,253.6	64,005.3	19,107.2	22,908.5
1974	121,324.8	68,806.5	18,434.6	25,347.6
1975	140,058.6	71,543.2	17,024.1	24,613.7
1976	160,296.3	75,041.3	18,454.6	26,323.5
1977	178,416.2	77,877.6	19,723.3	26,445.1
1978	195,773.1	79,572.8	21,579.3	27,882.5
1979	223,519.7	83,155.9	22,484.6	29,906.6
1980	251,934.3	84,294.9	22,523.9	30,476.1
1981	289,953.2	88,673.4	22,962.0	32,656.9
1982	303,370.4	82,043.2	22,863.6	27,597.4
1983	325,320.1	85,061.9	24,502.5	31,255.9
1984	354,912.4	89,998.8	28,848.9	36,952.0
1985	381,532.8	95,346.7	30,470.0	39,900.3
1986	400,868.5	99,182.6	32,338.3	43,010.6
1987	441,654.0	104,224.5	34,022.8	45,306.2
1988	477,976.4	109,929.7	36,729.0	51,355.7
1989	511,595.3	114,203.5	36,804.5	54,477.2
1990	522,898.4	112,799.5	39,157.3	55,453.6
1991	521,715.0	110,896.9	40,055.2	56,670.4
1992	535,229.8	112,486.8	43,248.8	59,988.7
1993	550,914.6	112,495.6	48,410.4	64,996.2
1994	593,111.9	117,659.9	54,678.8	71,162.9
1995	621,544.8	119,301.3	59,247.3	75,749.0
1996	665,807.1	124,642.6	62,733.7	79,249.4
1997	696,031.2	133,170.2	67,840.1	91,332.8
1998	697,560.0	133,753.3	72,724.5	96,903.5

TABLE A4

CANADIAN PRICE COMPONENTS OF NOMINAL GDP, 1962-98

YEAR	p_D^t	p_X^t	p_M^t
1962	1.0000	1.0000	1.0000
1963	1.0228	1.0015	0.9929
1964	1.0447	1.0118	0.9924
1965	1.0825	1.0482	1.0058
1966	1.1342	1.0839	1.0177
1967	1.1782	1.1123	1.0414
1968	1.2169	1.1545	1.0517
1969	1.2728	1.2030	1.0836
1970	1.3259	1.2216	1.1062
1971	1.3824	1.2719	1.1429
1972	1.4580	1.3191	1.1711
1973	1.5798	1.5010	1.2459
1974	1.7994	1.9004	1.4802
1975	2.0253	2.1430	1.6787
1976	2.1788	2.2860	1.7244
1977	2.3219	2.4902	1.9482
1978	2.4880	2.7228	2.1863
1979	2.7065	3.1933	2.4523
1980	2.9535	3.7167	2.6494
1981	3.2638	3.9776	2.7802
1982	3.5395	4.0485	2.8837
1983	3.6989	4.0782	2.8552
1984	3.8291	4.1993	2.9997
1985	3.9345	4.2655	3.0973
1986	4.0420	4.2144	3.1693
1987	4.1960	4.2831	3.1208
1988	4.3447	4.2772	3.0518
1989	4.5252	4.3577	3.0395
1990	4.6456	4.3160	3.0680
1991	4.7387	4.1359	2.9903
1992	4.7744	4.2261	3.0772
1993	4.8851	4.3827	3.2434
1994	4.9733	4.6340	3.4489
1995	5.0107	4.9296	3.5419
1996	5.0688	4.9497	3.4889
1997	5.1212	4.9097	3.4930
1998	5.1528	4.8984	3.5900

TABLE A5

GDP PRICE AND QUANTITY EFFECTS FOR CANADA, 1962-98

YEAR	b_D^t	b_X^t	b_M^t	c_L^t	c_{NR}^t	c_{ME}^t	c_{IS}^t
1962	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1963	1.0232	1.0003	1.0016	1.0152	1.0060	1.0014	1.0023
1964	1.0453	1.0026	1.0018	1.0412	1.0120	1.0037	1.0036
1965	1.0836	1.0106	0.9986	1.0673	1.0194	1.0081	1.0049
1966	1.1363	1.0182	0.9957	1.0935	1.0274	1.0143	1.0080
1967	1.1809	1.0244	0.9901	1.1107	1.0365	1.0226	1.0109
1968	1.2197	1.0338	0.9877	1.1212	1.0441	1.0297	1.0118
1969	1.2759	1.0449	0.9801	1.1388	1.0509	1.0343	1.0134
1970	1.3288	1.0491	0.9749	1.1413	1.0573	1.0395	1.0166
1971	1.3847	1.0604	0.9669	1.1539	1.0643	1.0442	1.0173
1972	1.4602	1.0706	0.9608	1.1773	1.0710	1.0485	1.0179
1973	1.5824	1.1092	0.9445	1.2210	1.0773	1.0531	1.0181
1974	1.8046	1.1867	0.8976	1.2503	1.0842	1.0601	1.0188
1975	2.0378	1.2265	0.8641	1.2635	1.0914	1.0681	1.0214
1976	2.1966	1.2474	0.8574	1.2886	1.0993	1.0757	1.0224
1977	2.3434	1.2764	0.8280	1.2922	1.1064	1.0829	1.0246
1978	2.5132	1.3097	0.7998	1.3286	1.1137	1.0889	1.0274
1979	2.7359	1.3762	0.7710	1.3628	1.1209	1.0953	1.0289
1980	2.9850	1.4461	0.7519	1.3845	1.1294	1.1032	1.0307
1981	3.2964	1.4782	0.7405	1.4013	1.1391	1.1126	1.0296
1982	3.5683	1.4863	0.7328	1.3481	1.1490	1.1242	1.0301
1983	3.7229	1.4897	0.7347	1.3472	1.1568	1.1306	1.0276
1984	3.8498	1.5039	0.7242	1.3794	1.1633	1.1356	1.0269
1985	3.9533	1.5119	0.7168	1.4101	1.1694	1.1407	1.0284
1986	4.0604	1.5057	0.7114	1.4456	1.1757	1.1472	1.0292
1987	4.2143	1.5139	0.7150	1.4785	1.1809	1.1544	1.0297
1988	4.3628	1.5132	0.7202	1.5151	1.1862	1.1629	1.0306
1989	4.5450	1.5223	0.7212	1.5302	1.1923	1.1732	1.0312
1990	4.6667	1.5177	0.7190	1.5315	1.1982	1.1832	1.0321
1991	4.7607	1.4971	0.7250	1.4912	1.2034	1.1903	1.0317
1992	4.7967	1.5077	0.7181	1.4792	1.2078	1.1963	1.0314
1993	4.9080	1.5278	0.7045	1.4942	1.2104	1.2018	1.0316
1994	4.9959	1.5628	0.6874	1.5280	1.2131	1.2059	1.0313
1995	5.0324	1.6068	0.6798	1.5528	1.2166	1.2112	1.0321
1996	5.0882	1.6098	0.6841	1.5596	1.2202	1.2175	1.0332
1997	5.1389	1.6037	0.6838	1.5750	1.2241	1.2247	1.0364
1998	5.1702	1.6018	0.6749	1.6082	1.2290	1.2350	1.0402

TABLE A6

THE DECOMPOSITION OF REAL GDP INTO GROWTH FACTORS

a^t	$*b_T^t$	$*c_L^t$	$*c_{NR}^t$	$*c_{ME}^t$	$*c_{IS}^t$	$(v^t/v^1)/b_D^t$
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0174	1.0194	1.0349	1.0411	1.0425	1.0448	1.0448
1.0542	1.0588	1.1025	1.1157	1.1198	1.1239	1.1239
1.0840	1.0939	1.1675	1.1902	1.1998	1.2057	1.2057
1.1118	1.1272	1.2326	1.2664	1.2845	1.2948	1.2948
1.1127	1.1286	1.2535	1.2992	1.3285	1.3430	1.3430
1.1336	1.1575	1.2978	1.3550	1.3953	1.4117	1.4117
1.1505	1.1781	1.3416	1.4100	1.4584	1.4779	1.4779
1.1747	1.2014	1.3712	1.4497	1.5070	1.5320	1.5320
1.1931	1.2233	1.4115	1.5022	1.5687	1.5958	1.5958
1.2020	1.2363	1.4555	1.5589	1.6345	1.6637	1.6637
1.2207	1.2789	1.5615	1.6822	1.7716	1.8036	1.8036
1.2152	1.2943	1.6182	1.7545	1.8600	1.8950	1.8950
1.2153	1.2879	1.6272	1.7759	1.8968	1.9373	1.9373
1.2344	1.3202	1.7012	1.8702	2.0119	2.0569	2.0569
1.2800	1.3529	1.7481	1.9341	2.0945	2.1461	2.1461
1.2663	1.3264	1.7622	1.9626	2.1371	2.1957	2.1957
1.2607	1.3377	1.8230	2.0434	2.2382	2.3028	2.3028
1.2305	1.3380	1.8525	2.0922	2.3081	2.3790	2.3790
1.2386	1.3559	1.9000	2.1642	2.4080	2.4794	2.4794
1.2265	1.3359	1.8009	2.0692	2.3263	2.3964	2.3964
1.2428	1.3603	1.8326	2.1200	2.3969	2.4631	2.4631
1.2751	1.3887	1.9155	2.2283	2.5304	2.5986	2.5986
1.2975	1.4062	1.9830	2.3190	2.6452	2.7203	2.7203
1.2947	1.3868	2.0048	2.3569	2.7039	2.7828	2.7828
1.3149	1.4233	2.1044	2.4850	2.8687	2.9540	2.9540
1.3155	1.4337	2.1722	2.5767	2.9964	3.0881	3.0881
1.3093	1.4375	2.1996	2.6226	3.0768	3.1728	3.1728
1.2916	1.4094	2.1584	2.5862	3.0600	3.1583	3.1583
1.2913	1.4016	2.0901	2.5152	2.9939	3.0890	3.0890
1.3178	1.4268	2.1106	2.5492	3.0496	3.1452	3.1452
1.3111	1.4111	2.1084	2.5521	3.0672	3.1640	3.1640
1.3511	1.4516	2.2180	2.6907	3.2447	3.3464	3.3464
1.3497	1.4742	2.2890	2.7849	3.3729	3.4813	3.4813
1.3990	1.5408	2.4029	2.9320	3.5698	3.6884	3.6884
1.4228	1.5601	2.4573	3.0079	3.6838	3.8178	3.8178
1.3856	1.4978	2.4088	2.9604	3.6561	3.8030	3.8030

Note: * Result from the previous column.

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A Comparison of Industrial Productivity Growth in Canada and the United States

INTRODUCTION

THE PURPOSE OF THIS STUDY is to provide a consistent international comparison of the patterns of growth in Canadian and U.S. industries. While much comparative work has been done with respect to sectoral (total factor) productivity[1] in the two countries, it has often been based on concepts that are not entirely comparable. Our approach here is to use methods and definitions that are almost identical for the two countries and, therefore, to provide a better sense of their relative productivity performance.

We find that during the 1961-73 period, Canadian industries were able to bring their productivity levels closer to U.S. levels and also had a higher rate of output growth. After 1973, however, output and productivity growth in the aggregate business sector slowed down in both countries. The productivity growth of the business sector was almost identical in the two countries during the 1973-95 period. As a result, the gap in productivity levels between the Canadian and U.S. private business sectors remained virtually unchanged after 1973.

Behind the overall trend in the growth of Canadian and U.S. industries, there is substantial variation across industrial sectors. The primary objective of this study is to characterize the patterns of growth for each of 33 industrial sectors in the two countries. We decompose the growth of industrial output into the contributions of capital, labour, and intermediate inputs, and productivity growth. We find that input growth was the predominant source of output growth for almost all industries in the two countries over the 1961-95 period. Productivity growth contributed, on average, only about 20 percent of industrial output growth in the two countries during this period.

Our methodology for making international comparisons of growth in output, input, and productivity is based on the economic theory of production. We use measures of labour and capital that take into account the changing composition of the labour force and capital stocks (relatively more educated and older workers, and relatively more equipment compared to structures). We show that the rise in the quality[2] of labour and capital inputs plays a significant role in the economic growth of both countries.

The study is organized as follows. In the section entitled *Methodology*, we outline the theoretical framework for making international comparisons. In the section entitled *Data*, we present a brief discussion of the data used in the measurement of industrial output and input in the two countries. Our empirical findings about the patterns of growth in Canada and the United States are summarized in the next section. Finally, we present our conclusions.

METHODOLOGY

OUR METHODOLOGY FOR MODELING PRODUCTION follows that of Jorgenson, Gollop, and Fraumeni (1987) and we will merely summarize that approach here. One may view output as being produced with different types of labour, capital, and intermediate inputs. That is, one may write the production function as:

$$(1) \quad Q_{it} = f(K^i_{1t}, K^i_{2t}, \ldots, K^i_{pt}, L^i_{1t}, L^i_{2t}, \ldots, L^i_{qt}, X^i_{1t}, X^i_{2t}, \ldots, X^i_{rt}, t),$$

where Q_{it} is the quantity of output for sector i in period t; K^i_{jt}, the various types of capital input (structures, high-tech equipment, low-tech equipment, etc.); and L^i_{jt} and M^i_{jt}, the various labour and intermediate inputs. The last argument, t, is an index of the level of technology. Such an approach would allow, for example, skilled and unskilled workers to have different elasticities of substitution with different types of capital equipment. However appealing such an approach may be, it is not practicable for a large number of inputs and we assume that the production function can be simplified to:

$$(2) \quad Q_{it} = f(K_{it}, L_{it}, M_{it}, t),$$

with

$$(3) \quad K_{it} = k(K^i_{1t}, K^i_{2t}, \ldots, K^i_{pt}), \; L_{it} = l(L^i_{1t}, L^i_{2t}, \ldots, L^i_{qt}),$$

and $M_{it} = m(M^i_{1t}, M^i_{2t}, \ldots, M^i_{rt})$.

The requirements for such an aggregation process are well known and we refer the reader to Jorgenson, Gollop and Fraumeni (1987).

We assume that technology is characterized by constant returns to scale and define the cost of capital (P^K_{it}) in such a way that the value of output is equal to the value of all inputs from the point of view of the producer. This is unlike approaches that do not impose such an equality and calculate the cost of capital by other methods (for example, Hall, 1988). Denoting the price of output to the producer by P_{it} we have:

$$(4) \quad M_{it} = m\,(M^i_{1t}, M^i_{2t}, \ldots, M^i_{rt}),$$

where $P^K_{it}, P^L_{it}, P^M_{it}$ are the prices of the respective input aggregates. The term for labour, for example, represents total labour compensation paid by producer i,

$$(5) \quad P^L_{it} L_{it} = P^{Li}_{1t} L^i_{1t} + P^{Li}_{2t} L^i_{2t} + \ldots + P^{Li}_{qt} L^i_{qt},$$

where P^L_{it} is the price of type j labour.

We describe the aggregation process (3) in detail below. For the time being, we concentrate on the production constraints described by Equations (2) and (4). To construct an index of productivity for each sector i, we assume that the production function (2) may be written in a Hicks-neutral[3] translog form: $\ln Q_{it} = a(t) + f(\ln K_{it}, \ln L_{it}, \ln M_{it})$.

Specifically, the translog index of the rate of growth of productivity is given by:

$$(6) \quad \ln \frac{A_{it}}{A_{it-1}} = \ln \frac{Q_{it}}{Q_{it-1}} - \bar{v}^K_{it} \ln \frac{K_{it}}{K_{it-1}} - \bar{v}^L_{it} \ln \frac{L_{it}}{L_{it-1}} - \bar{v}^M_{it} \ln \frac{M_{it}}{M_{it-1}},$$

where A_{it} is the index of technology in sector i, and the weights are input value shares:

$$(7) \quad \bar{v}^K_{it} = 1/2\,(v^K_{it} + v^K_{it-1}); \quad v^K_{it} = \frac{P^K_{it} K_{it}}{P_{it} Q_{it}};$$

$$\bar{v}^L_{it} = 1/2\,(v^L_{it} + v^L_{it-1}); \quad v^L_{it} = \frac{P^L_{it} L_{it}}{P_{it} Q_{it}}; \text{ and}$$

$$\bar{v}^M_{it} = 1/2\,(v^M_{it} + v^M_{it-1}); \quad v^M_{it} = \frac{P^M_{it} M_{it}}{P_{it} Q_{it}}.$$

The advantages of a chain index like (6) over the fixed-weight indices are well known and we need not elaborate here. We now turn to the construction of the input aggregates.

In constructing the input aggregates for capital, labour, and intermediate inputs, we impose separability assumptions as alluded to in Equations (2) and (3) above. The construction of capital input aggregates is discussed in detail in Jorgenson and Lee (2001), in Appendix E for Canada, and in Appendix B for the United States; the method for labour input is given in Appendix C for the United States, and in Appendix F for Canada. We will merely summarize the main points here.

The capital input index for each sector is constructed in a way that recognizes the trade-off between detail and tractability. We have chosen to build up from four components — structures, equipment, land, and inventories. Beginning with investment data, we use the perpetual inventory method to derive the various stocks of capital, A^i_{jt}. The stock of type j created at the end of period t–1 produce a flow of capital services K^i_{jt} in period t. We assume that the quantity of services is proportional to the stocks:

$$(8) \quad K^i_{jt} = q^K_j A^i_{jt-1} .$$

Note that the proportionality constant, q^K_j, is independent of time, hence the term "constant quality index." These flows of services from the various types of capital inputs are then aggregated, using the rental costs of capital, P^{Ki}_{jt}, derived from sectoral value-added data. We express the total flow of capital input into sector i as a translog function of the components:

$$(9) \quad \ln\frac{K_{it}}{K_{it-1}} = \sum_j 1/2\,(v^{Ki}_{jt} + v^{Ki}_{jt-1}) \ln\frac{K^i_{jt}}{K^i_{jt-1}} = \sum_j 1/2\,(v^{Ki}_{jt} + v^{Ki}_{jt-1}) \ln\frac{A^i_{jt}}{A^i_{jt-1}} ,$$

where the weights are the value shares of total capital input:

$$(10) \quad v^{Ki}_{jt} = \frac{P^{Ki}_{jt} K^i_{jt}}{P^K_{it} K_{it}} , \quad (j = 1,2,\dots,p) ,$$

$$\text{and } P^K_{it} K_{it} = P^{Ki}_{1t} K^i_{1t} + P^{Ki}_{2t} K^i_{2t} + \dots + P^{Ki}_{pt} K^i_{pt} .$$

In our analysis, we separate the growth of capital inputs into the effect of capital accumulation and the effect of substitution among different types of physical assets. The contribution of substitution among components of aggregate capital, which Jorgenson calls the quality index of capital input, is measured as:

$$(11) \quad q^K_{it} = \frac{K_{it}}{A_{it-1}} ,$$

where the total capital stock A_{it} of sector i is defined as the unweighted sum of the individual stocks:

$$(12)\quad A_{it}=\sum_{j} A^{i}_{jt}\ .$$

The labour input is constructed in a similar manner. While it might be argued that various categories of labour are not perfect substitutes (for example, physicists for engineers), that level of detail is clearly not practical and we have chosen to divide the labour force into sex, age, educational attainment, and employment category, as shown in Tables 1 and 2. All workers in a particular category are assumed to earn the same wage and to have the same marginal product. As in Equation (8) above (for capital services), we assume that the flow of effective labour services from group j is proportional to the annual number of hours worked by all workers in j, $L^{i}_{jt}=q^{L}_{j}\, H^{i}_{jt}$, where j runs over all the cells cross-classified by the different categories of workers. For Canada, the total number of cells in each sector is $q = 168$. The total labour input into sector i is then the translog aggregate over j:

$$(13)\quad \ln\frac{L_{it}}{L_{it-1}}=\sum_{j} 1/2\,(v^{Li}_{jt}+v^{Li}_{jt-1})\ln\frac{L^{i}_{jt}}{L^{i}_{jt-1}}=\sum_{j} 1/2\,(v^{Li}_{jt}+v^{Li}_{jt-1})\ln\frac{H^{i}_{jt}}{H^{i}_{jt-1}}\ ,$$

where the weights are the value shares:

$$v^{Li}_{jt}=\frac{P^{Li}_{jt}L^{i}_{jt}}{\sum_{k} P^{Li}_{kt}L^{i}_{kt}}\ ,\quad (j=1,2,\ldots,q)\ .$$

We also wish to decompose the increase in labour input into changes in hours worked and changes in the composition of workers. The measure for the changes in composition, also called quality of labour by Jorgenson, is given as:

$$(14)\quad q^{L}_{it}=\frac{L_{it}}{\sum_{j} H^{i}_{jt}}\ .$$

Finally, the intermediate input aggregate is defined similarly as a translog aggregate over the various commodities:[4]

$$(15)\quad \ln\frac{M_{it}}{M_{it-1}}=\sum_{j=1}^{r} 1/2\,(v^{Mi}_{jt}+v^{Mi}_{jt-1})\ln\frac{M^{i}_{jt}}{M^{i}_{jt-1}}\ .$$

TABLE 1

CLASSIFICATION OF THE CANADIAN WORKFORCE

WORKER CHARACTERISTICS	NUMBER OF CATEGORIES	TYPE
Sex	2	Female; Male
Employment Category	3	Paid Employees; Self-employed; Unpaid Family Workers
Age	7	15-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	0-8 Years Grade School; Some or Completed High School; Some or Completed Post-secondary; University or Above

TABLE 2

CLASSIFICATION OF THE U.S. WORKFORCE

WORKER CHARACTERISTICS	NUMBER OF CATEGORIES	TYPE
Sex	2	Female; Male
Employment Category	2	Paid Employees; Self-employed and Unpaid Family Workers
Age	7	16-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	6	0-8 Years Grade School; 1-3 Years High School; 4 Years High School; 1-3 Years College; 4 Years College; 5+ Years College

DATA

THE STARTING POINT FOR IMPLEMENTING the above methodology is the production account of each industry in both countries (for details, see Jorgenson, Kuroda, and Nishimizu, 1987). This includes data on price and quantity indices of output, capital inputs, labour inputs, and intermediate inputs (including energy, materials, and services) for each industry.[5] The value of output in Equation (2) is defined from the point of view of the producer. This includes subsidies but excludes all indirect taxes on output as well as trade and transportation margins incurred in the delivery of output to other sectors.

Similarly, the value of inputs is defined from the producer-purchaser's point of view. The value of labour inputs includes all taxes levied on labour and all costs incurred in the employment of labour, such as insurance and other fringe benefits. The value of capital inputs includes all taxes levied on the ownership and utilization of capital, such as property taxes and corporate income taxes. The value of intermediate inputs includes all taxes, as well as trade and transportation margins associated with taking deliveries of intermediate inputs from other sectors.

INTERMEDIATE INPUT DATA

FOR CANADA, THE INDUSTRY PRODUCTION ACCOUNT is estimated from the annual input-output (I-O) tables (see Durand, 1998, on the transformation of annual input-output tables for productivity analysis). Production accounts were estimated for 122 industries in Canada and 35 industries in the United States. Accounts for these industries were then consolidated into a common set of 33 industries making up the private business sector for the purpose of this study.[6]

The industry production account for the United States is an update and modification of that found in Jorgenson, Gollop and Fraumeni (1987). The I-O data for 1977-95 come from the U.S. Bureau of Labor Statistics (BLS) and were linked to the pre-1977 tables described in Jorgenson and Wilcoxen (1990).[7]

LABOUR INPUT DATA

PRICE AND QUANTITY INDICES OF LABOUR INPUTS for each industry in both countries are measured on the basis of labour compensation and hours worked, disaggregated by sex, age, educational attainment, and employment category.[8] To ensure the comparability of labour input measures between Canada and the United States, we employed a similar classification scheme for the workforce in the two countries, as shown in Tables 1 and 2. We have seven age groups and four to six educational levels.[9] Due to the different methods of estimating compensation, we also divided workers into employees and self-employed or unpaid family workers,[10] giving a total of 168 cells.

For the United States, the data are derived from the decennial Census of the Population, supplemented by the annual Demographic Surveys.[11] The data set consists of the number of workers, their annual weeks worked, their average hours per week, and their wage rates, for each cell. Compensation rates for each cell are calculated so that the totals of each industry match those of the National Income Accounts.

For Canada, the data are derived from the Census of Population, supplemented by the annual Surveys of Consumer Finance and the monthly Labour Force Surveys. The data set includes hours worked and labour compensation for each type of worker, cross-classified by sex, age, educational attainment, employment category, and industry. The estimates of hours worked and labour compensation for each industry are adjusted to official measures of hours worked and compensation produced by Statistics Canada.

CAPITAL INPUT DATA

TO IMPLEMENT EQUATION (9) FOR CAPITAL INPUT, data on property compensation and capital stocks are required. For both Canada and the United States, industry capital stocks are aggregated from four asset types — non-residential structures, machinery and equipment, land, and inventories.[12] For comparability, the two "structures" categories (building and engineering) in the Canadian data were added to form one asset type, while the 56 categories of producer durable equipment in the U.S. data were added to form "machinery and equipment."

The capital stock for the United States is estimated from investment data using geometric depreciation. These U.S. estimates use a 1.65 declining-balance rate for most machinery and equipment, and a 0.9 declining-balance rate for most non-residential structures. The capital stock data published by Statistics Canada are based on a modified double-declining-balance method for both machinery and equipment, and structures. To ensure comparability between Canadian and U.S. capital stock estimates, we obtained an alternative set of capital stock estimates from the Investment and Capital Stock Division of Statistics Canada (see Appendix G, in Jorgenson and Lee, 2001). These alternative capital stocks estimates are based on the same declining-balance rates as those used for the United States. These estimates underlie our analysis of patterns of growth in Canadian and U.S. industries. However, for a comparison, we also present the results obtained with capital stocks used in Statistics Canada's productivity estimates shown in Appendix B.

The cost of capital for each asset is derived from sectoral value-added data using an equation that involves taxes and rates of return. Given the stocks described above, the P_{jt}^{Ki} in Equation (9) is scaled so that the total value of capital inputs for sector *i* is equal to the sectoral value added of capital in the National Income Accounts for the United States and the KLEMS database for Canada.[13]

OUTPUT GROWTH AND PRODUCTIVITY GROWTH

BEFORE DISCUSSING THE RESULTS, we should emphasize that we are comparing growth rates here. The comparison of *absolute* productivity differences between the two countries is presented in Chapter 3 of this volume. Given the finding there that Canada had a lower absolute productivity at the beginning of the sample period, a more rapid growth rate in Canada means a closing of the productivity gap with the United States.

PRIVATE BUSINESS SECTOR

TO GIVE AN OVERVIEW OF THE ECONOMY, we shall first examine the entire business sector and then consider sectoral estimates in the next section. For this, we use an approach similar to Jorgenson and Stiroh (1999), which expresses total value added as a function of capital, labour, and technology. Table 3 decomposes the growth of value added in the private business sector into the contributions of capital quantity and quality, labour quantity and quality, and productivity growth. The output of the private business sector grew faster in Canada than in the United States before 1988. For the most recent period — 1988-95 — output growth was slower in Canada: 1.5 percent versus 2.2 percent per year for the United States. The dominant factors of growth were increases in capital and labour inputs for both countries, with productivity growth contributing less than a third. For the entire period, capital input growth contributed 1.1 percent of the 3.7 percent rate of output growth in Canada, labour contributed 1.4 percent, and productivity growth 1.2 percent. The 1.1 percent capital input contribution can be decomposed further into 0.9 percent for capital accumulation and 0.2 percent for quality change. Similarly, the 1.4 percent labour input contribution is made up of 1.1 percent for increased hours worked and 0.3 percent for quality change. In the United States, of the 3.1 percent output growth rate, capital, labour, and productivity contributions were 1.0, 1.4, and 0.8 percent, respectively. One can see that quality changes in labour are roughly similar in the two countries, while capital quality growth is higher in the United States.

Productivity growth slowed down after 1973 in both countries, but the decline was more pronounced in Canada. Before 1973, productivity growth in the Canadian business sector was 2.5 percent per year, higher than the 1.6 percent rate recorded in the United States. After 1973, productivity growth was quite similar in the two countries. During 1988-95, productivity grew at about the same rate in both countries: 0.1 percent per year.

A COMPARISON ACROSS 33 INDUSTRIES

WE NOW TURN TO SECTORAL PERFORMANCE, measured with the methodology outlined in the section entitled *Methodology*. Table 4 shows average annual growth rates of gross output in Canadian and U.S. industries over the period 1961-95 and in the three sub-periods (1961-73, 1973-88, and 1988-95).[14] The table also shows unweighted averages across the 33 industries. Before 1988, average growth rates of output in Canada were higher than in the United States for almost all industries, in particular mining and vehicles. After 1988, output growth in Canada was slower than in the United States in 21 of the 33 industries.

TABLE 3

SOURCES OF OUTPUT GROWTH IN THE PRIVATE BUSINESS SECTOR, IN CANADA AND THE UNITED STATES (AVERAGE % GROWTH PER YEAR)

	1961-95	1961-73	1973-88	1988-95
		CANADA		
Value Added	3.71	5.56	3.27	1.48
Contribution of Capital Stock	0.96	1.05	1.05	0.60
Contribution of Capital Quality	0.18	0.24	0.16	0.13
Contribution of Hours Worked	1.07	1.29	1.30	0.22
Contribution of Labour Quality	0.33	0.47	0.19	0.38
Productivity Growth	1.17	2.51	0.57	0.15
		UNITED STATES		
Value Added	3.14	4.41	2.57	2.18
Contribution of Capital Stock	0.62	0.68	0.65	0.44
Contribution of Capital Quality	0.33	0.51	0.28	0.13
Contribution of Hours Worked	1.08	1.08	1.06	1.10
Contribution of Labour Quality	0.36	0.50	0.24	0.39
Productivity Growth	0.75	1.64	0.34	0.12

Tables 5 and 6 divide sectoral output growth into growth of all inputs and growth in total factor productivity (TFP). In line with the higher output growth, annual input growth rates in Canada were higher than in the United States in 28 of the 33 industries over the 1961-73 period, and in 29 industries over the 1973-88 period. For the period 1988-95, input growth rates were virtually identical in the two countries. A comparison of these two tables shows that the predominant source of output growth in most industries was the growth of capital, labour, and intermediate inputs, with TFP contributing only about a fifth in both countries. For the most recent period (1988-95), the contributions of capital, labour, and intermediate inputs were the predominant sources of output growth in 19 of 33 industries in Canada and in 21 of 33 industries in the United States.

In Table 6, we can see that most industries suffered a productivity growth slowdown after 1973, as noted above for the aggregate private business sector of both countries. Before 1973, productivity growth in most Canadian industries exceeded that of their U.S. counterparts, with the exception of food, tobacco, paper, printing, chemicals, petroleum refining, other transportation equipment, the finance, insurance, and real estate group (FIRE), and other services. After 1973, productivity in Canadian industries grew at a rate similar to that of U.S. industries. For the most recent period (1988-95), 13 of the 33 Canadian industries had faster TFP growth than their U.S. counterparts, including notably the

FIRE, communications, transportation equipment, chemicals, lumber and wood, and crude petroleum and gas sectors.

In tables 7 to 9, we present the growth of capital, labour, and intermediate inputs separately. An interesting feature of economic growth in Canada has been the high growth rates of intermediate inputs for almost all industries during the first two periods, 1961-73 and 1973-88. The growth rates of intermediate inputs were higher in 29 Canadian industries during first two periods and in 15 industries during the most recent period, 1988-95. In both countries, there has been a steady slowdown in the growth of capital, labour, and intermediate inputs in most industries since 1961. For example, the growth of capital input in Canada declined in 28 industries between 1961-73 and 1973-88, and in 24 industries between 1973-88 and 1988-95. In the United States, the growth of capital input declined in 24 industries between 1961-73 and 1973-88, and in 29 industries between 1973-88 and 1988-95. This steady slowdown in capital input growth occurred despite the rapid growth of investments in high-tech assets such as computers (Ho, Jorgenson and Stiroh, 1999).

Recall from Equations (11) and (14) that we divide the growth of factor inputs into quantity and quality growth (composition change). Table 10 shows the results for capital quality growth in the two countries. Capital quality increased in almost all industries in both countries during all three periods. The growth rates of capital quality in Canada were higher in 10 industries from 1961 to 1973, and in 13 industries for the subsequent period 1973-88. For the 1988-95 period, 20 of the 33 Canadian industries had higher growth of capital quality, mainly as a result of a faster shift toward machinery and equipment in the composition of capital stocks in Canada. A closer look at the data reveals that the Canadian sectors which experienced substantially higher growth rates of capital quality over the period 1988-95 include lumber and wood, furniture, rubber and plastics, motor vehicles, trade, and other services. In the United States, sectors that experienced higher growth rates include agriculture, forestry and fisheries, electrical machinery, and FIRE.

Table 11 shows annual average growth rates of labour quality in Canadian and U.S. industries. For the entire period, labour quality increased in all industries in both countries. The growth rates of labour quality in Canada were lower in 19 industries over the 1961-73 period, and in 22 industries over the 1973-88 period. For the most recent period (1988-95), the growth of labour quality was slower in Canada in almost all industries except crude petroleum and gas, petroleum refining, transportation and warehouse, and other services. The sectors with the largest gaps in the growth of labour quality were FIRE, communications, leather, lumber and wood, apparel, and coal mining, although the differences here are modest compared to the differences in capital quality growth.

TABLE 4

OUTPUT GROWTH IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	3.21	3.25	3.80	1.90	1.60	1.78	0.99	2.57
2. Metal Mining	2.09	4.26	1.33	0.01	0.34	1.68	-2.73	4.62
3. Coal Mining	5.46	5.96	7.79	-0.39	2.75	3.20	3.13	1.14
4. Crude Pet. and Gas	4.67	10.50	0.41	3.78	0.29	2.48	-0.39	-2.02
5. Non-met. Mining	3.19	6.84	2.21	-1.00	1.38	3.49	-0.05	0.80
6. Construction	2.31	4.09	2.76	-1.69	1.18	2.57	0.79	-0.38
7. Food	2.05	3.39	1.63	0.63	2.17	2.63	1.99	1.76
8. Tobacco	0.15	2.18	-1.10	-0.65	0.05	0.85	-0.64	0.16
9. Textile	2.59	6.04	1.60	-1.20	2.27	3.88	1.48	1.22
10. Apparel	1.96	4.82	1.43	-1.80	2.06	4.22	0.55	1.60
11. Lumber and Wood	3.36	4.87	3.13	1.26	2.40	4.64	1.73	-0.01
12. Furniture	3.18	6.88	2.24	-1.17	3.08	5.41	1.76	1.91
13. Paper	2.77	4.68	1.85	1.46	2.76	4.68	1.96	1.21
14. Printing	2.57	3.86	3.83	-2.35	2.46	3.26	3.01	-0.10
15. Chemicals	4.32	6.37	3.98	1.52	3.32	6.54	1.58	1.52
16. Petroleum Refining	2.40	6.18	-0.12	1.32	2.19	3.63	1.93	0.26
17. Rubber and Plastics	5.98	10.10	4.07	3.02	5.05	8.59	2.67	4.10
18. Leather	-1.23	0.88	-0.60	-6.18	-2.13	-0.51	-2.84	-3.36
19. Stone, Clay and Glass	2.02	6.10	1.05	-2.89	1.59	3.80	0.33	0.48

TABLE 4 (CONT'D)

	Canada				United States			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	2.67	5.18	1.31	1.28	0.74	4.15	-2.12	1.01
21. Fabricated Metals	2.86	6.80	1.55	-1.08	2.21	4.90	0.31	1.66
22. Non-elec. Machinery	5.81	7.87	3.32	7.64	4.79	6.14	3.19	5.91
23. Electrical Machinery	4.55	7.26	2.97	3.26	5.10	6.88	3.27	5.97
24. Motor Vehicles	7.68	13.69	4.18	4.87	3.49	6.55	1.18	3.21
25. Other Trans. Equip.	3.18	4.23	2.45	2.94	1.42	2.75	2.48	-3.13
26. Misc. Manufacturing	3.06	5.95	2.05	0.28	3.61	5.34	3.50	0.86
27. Trans. and Warehouse	3.96	6.01	3.35	1.75	3.26	4.60	2.10	3.44
28. Communications	7.25	8.68	7.38	4.52	5.01	6.05	5.02	3.21
29. Electric Utilities	5.32	8.45	4.56	1.56	3.55	5.92	2.73	1.26
30. Gas Utilities	4.60	8.23	3.20	1.39	0.02	4.61	-2.44	-2.60
31. Trade	4.34	5.76	4.14	2.35	3.64	4.76	2.86	3.40
32. Finance, Ins. and Real Estate	4.37	5.21	4.22	3.26	3.44	4.15	3.83	1.39
33. Other Services	4.61	5.43	4.92	2.54	4.43	6.30	3.53	3.16
Average	3.55	6.06	2.75	0.97	2.41	4.24	1.42	1.40

TABLE 5

INPUT GROWTH IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	2.14	2.11	2.86	0.63	0.38	1.63	-0.54	0.20
2. Metal Mining	2.64	4.93	1.53	1.10	-0.51	2.96	-3.51	-0.03
3. Coal Mining	3.01	3.14	4.84	-1.12	1.52	3.73	1.96	-3.24
4. Crude Pet. and Gas	6.12	8.02	6.68	1.69	1.27	1.65	2.66	-2.37
5. Non-met. Mining	2.56	5.12	1.82	-0.23	1.02	2.42	-0.20	1.21
6. Construction	2.10	4.16	2.06	-1.37	1.84	3.18	1.29	0.72
7. Food	1.85	2.83	1.72	0.43	1.42	1.96	1.02	1.38
8. Tobacco	-0.37	1.50	-1.73	-0.66	0.01	-0.57	0.41	0.17
9. Textile	1.39	4.48	0.42	-1.83	0.76	3.35	-0.92	-0.08
10. Apparel	1.07	3.89	0.52	-2.59	0.97	3.42	-0.88	0.75
11. Lumber and Wood	2.74	4.09	2.02	1.94	2.48	4.95	0.69	2.09
12. Furniture	2.58	5.14	2.77	-2.22	2.37	4.79	0.84	1.51
13. Paper	2.74	4.49	1.88	1.55	2.47	3.84	1.73	1.72
14. Printing	2.56	3.38	3.33	-0.47	2.54	2.74	3.18	0.79
15. Chemicals	3.32	4.94	3.31	0.58	2.70	4.87	1.66	1.22
16. Petroleum Refining	2.09	5.57	-0.24	1.11	1.30	2.42	0.63	0.80
17. Rubber and Plastics	4.84	7.96	3.58	2.19	3.92	6.98	1.81	3.18
18. Leather	-1.81	0.26	-1.64	-5.73	-2.23	0.11	-3.65	-3.20
19. Stone, Clay and Glass	1.48	4.27	0.97	-2.21	1.08	3.26	-0.15	-0.01

TABLE 5 (CONT'D)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	2.23	4.50	1.12	0.71	0.48	3.97	-2.28	0.41
21. Fabricated Metals	2.17	5.60	1.19	-1.59	1.62	4.07	-0.13	1.14
22. Non-elec. Machinery	4.80	6.37	2.94	6.11	3.09	5.36	1.23	3.17
23. Electrical Machinery	3.30	5.22	2.08	2.64	3.11	5.15	1.49	3.08
24. Motor Vehicles	6.39	11.15	3.47	4.51	3.31	6.01	1.19	3.22
25. Other Trans. Equip.	2.79	3.77	2.63	1.43	0.93	1.96	2.00	-3.14
26. Misc. Manufacturing	2.41	4.59	1.92	-0.30	2.45	3.82	2.23	0.56
27. Trans. and Warehouse	2.76	3.28	2.57	2.29	2.23	2.66	1.56	2.94
28. Communications	3.90	4.27	3.99	3.06	4.37	5.34	4.48	2.50
29. Electric Utilities	4.96	5.87	4.68	4.01	2.61	3.66	3.02	-0.05
30. Gas Utilities	4.11	3.93	4.31	3.99	0.56	3.88	-0.72	-2.38
31. Trade	3.00	3.71	2.79	2.21	3.00	4.01	2.47	2.40
32. Finance, Ins. and Real Estate	5.14	6.23	5.74	2.01	3.72	4.26	3.85	2.51
33. Other Services	5.01	5.26	5.55	3.45	4.93	5.74	4.70	4.02
Average	2.91	4.67	2.48	0.83	1.87	3.56	1.00	0.82

TABLE 6

PRODUCTIVITY GROWTH IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	1.08	1.14	0.94	1.27	1.22	0.16	1.53	2.37
2. Metal Mining	-0.55	-0.68	-0.19	-1.09	0.85	-1.29	0.77	4.66
3. Coal Mining	2.45	2.83	2.94	0.73	1.23	-0.53	1.17	4.38
4. Crude Pet. and Gas	-1.46	2.48	-6.26	2.09	-0.98	0.83	-3.05	0.35
5. Non-met. Mining	0.63	1.73	0.40	-0.77	0.36	1.07	0.15	-0.41
6. Construction	0.22	-0.07	0.69	-0.32	-0.66	-0.61	-0.50	-1.10
7. Food	0.20	0.56	-0.08	0.20	0.74	0.67	0.97	0.39
8. Tobacco	0.52	0.68	0.63	0.01	0.04	1.42	-1.04	-0.01
9. Textile	1.20	1.56	1.18	0.63	1.51	0.53	2.40	1.29
10. Apparel	0.89	0.92	0.91	0.79	1.08	0.80	1.43	0.84
11. Lumber and Wood	0.62	0.77	1.10	-0.68	-0.08	-0.31	1.04	-2.10
12. Furniture	0.60	1.74	-0.53	1.05	0.71	0.62	0.92	0.40
13. Paper	0.03	0.19	-0.03	-0.09	0.29	0.84	0.23	-0.51
14. Printing	0.01	0.49	0.51	-1.87	-0.08	0.52	-0.17	-0.90
15. Chemicals	0.99	1.43	0.67	0.94	0.62	1.68	-0.08	0.31
16. Petroleum Refining	0.32	0.62	0.12	0.22	0.89	1.22	1.30	-0.54
17. Rubber and Plastics	1.14	2.13	0.49	0.83	1.14	1.60	0.86	0.92
18. Leather	0.59	0.62	1.05	-0.45	0.11	-0.63	0.81	-0.16
19. Stone, Clay and Glass	0.54	1.83	0.08	-0.69	0.50	0.54	0.48	0.49

TABLE 6 (CONT'D)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	0.44	0.68	0.19	0.57	0.26	0.18	0.16	0.60
21. Fabricated Metals	0.69	1.20	0.36	0.51	0.59	0.83	0.44	0.52
22. Non-elec. Machinery	1.01	1.50	0.38	1.53	1.70	0.77	1.96	2.75
23. Electrical Machinery	1.24	2.05	0.89	0.62	1.99	1.73	1.79	2.89
24. Motor Vehicles	1.28	2.54	0.71	0.37	0.18	0.55	-0.01	-0.02
25. Other Trans. Equip.	0.39	0.46	-0.18	1.52	0.49	0.80	0.48	0.01
26. Misc. Manufacturing	0.66	1.36	0.13	0.58	1.16	1.52	1.27	0.30
27. Trans. and Warehouse	1.19	2.73	0.78	-0.54	1.02	1.93	0.54	0.50
28. Communications	3.35	4.41	3.39	1.46	0.64	0.71	0.54	0.71
29. Electric Utilities	0.36	2.58	-0.11	-2.44	0.94	2.26	-0.29	1.31
30. Gas Utilities	0.49	4.30	-1.11	-2.60	-0.54	0.73	-1.72	-0.22
31. Trade	1.35	2.05	1.35	0.14	0.64	0.75	0.39	1.00
32. Finance, Ins. and Real Estate	-0.77	-1.02	-1.51	1.24	-0.28	-0.11	-0.03	-1.11
33. Other Services	-0.40	0.18	-0.63	-0.91	-0.50	0.57	-1.18	-0.86
Average	0.65	1.39	0.28	0.15	0.54	0.68	0.41	0.58

TABLE 7

GROWTH OF CAPITAL INPUT IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	1.45	4.51	1.12	-3.07	1.73	1.92	1.14	2.66
2. Metal Mining	2.95	5.35	2.36	0.08	3.00	7.37	1.74	-1.82
3. Coal Mining	5.33	10.90	5.00	-3.53	4.13	4.15	6.65	-1.32
4. Crude Pet. and Gas	5.77	7.75	6.29	1.25	2.23	2.69	4.75	-3.94
5. Non-met. Mining	2.85	5.54	2.43	-0.86	3.07	4.95	2.14	1.85
6. Construction	1.55	1.48	1.44	1.93	1.31	3.34	1.56	-2.73
7. Food	2.30	4.07	1.57	0.81	3.12	4.20	3.46	0.54
8. Tobacco	0.17	2.28	-0.74	-1.50	2.49	0.03	5.17	0.94
9. Textile	1.05	4.20	-0.78	-0.42	2.94	3.29	3.38	1.41
10. Apparel	2.08	3.93	0.79	1.70	4.81	8.21	3.07	2.69
11. Lumber and Wood	2.35	4.82	1.33	0.29	2.30	2.86	2.96	-0.08
12. Furniture	1.70	4.03	1.65	-2.19	5.01	7.63	4.53	1.53
13. Paper	3.69	5.93	1.90	3.70	4.34	4.24	4.99	3.11
14. Printing	2.59	3.39	2.26	1.93	4.56	4.57	5.29	2.99
15. Chemicals	3.81	5.34	4.31	0.12	4.40	6.69	4.28	0.74
16. Petroleum Refining	2.98	3.92	3.41	0.47	2.50	3.29	1.42	3.46
17. Rubber and Plastics	3.87	6.15	2.45	3.02	5.27	6.36	5.48	2.96
18. Leather	0.45	2.45	-0.51	-0.90	0.36	1.09	0.89	-2.00
19. Stone, Clay and Glass	1.40	3.63	0.87	-1.26	2.19	2.87	3.65	-2.07

TABLE 7 (CONT'D)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	2.89	4.58	2.10	1.70	1.89	2.75	2.44	-0.76
21. Fabricated Metals	0.92	4.38	0.72	-4.56	3.18	5.17	3.27	-0.39
22. Non-elec. Machinery	2.49	3.87	1.29	2.68	4.75	5.69	5.40	1.74
23. Electrical Machinery	3.11	4.47	2.08	2.99	6.39	9.99	5.51	2.12
24. Motor Vehicles	4.75	5.00	5.48	2.75	3.04	5.21	2.35	0.78
25. Other Trans. Equip.	2.42	1.85	2.93	2.32	4.60	6.06	5.20	0.83
26. Misc. Manufacturing	3.44	6.21	1.99	1.80	4.91	5.43	5.33	3.13
27. Trans. and Warehouse	1.99	1.86	2.22	1.73	0.71	1.00	0.80	0.02
28. Communications	3.91	4.11	3.56	4.34	4.88	7.51	3.91	2.46
29. Electric Utilities	5.26	6.24	5.39	3.32	1.84	1.71	3.80	-2.16
30. Gas Utilities	4.79	5.16	4.96	3.79	3.55	3.77	3.16	4.01
31. Trade	2.34	2.23	2.18	2.87	4.62	5.95	4.22	3.19
32. Finance, Ins. and Real Estate	5.81	6.41	6.82	2.59	3.61	4.66	3.46	2.16
33. Other Services	6.62	6.06	7.43	5.86	5.10	7.22	3.78	4.27
Average	3.00	4.61	2.61	1.08	3.42	4.60	3.61	0.98

TABLE 8

GROWTH OF LABOUR INPUT IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	-0.98	-2.95	0.38	-0.51	-1.09	-2.08	-1.03	0.48
2. Metal Mining	0.78	1.23	0.76	0.07	-0.72	0.94	-2.80	0.91
3. Coal Mining	0.16	-2.57	2.94	-1.09	-0.16	2.04	-0.54	-3.13
4. Crude Pet. and Gas	5.99	8.96	7.01	-1.29	0.67	-1.08	3.54	-2.50
5. Non-met. Mining	1.11	2.21	0.03	1.55	0.47	0.54	0.14	1.05
6. Construction	1.50	2.65	1.81	-1.12	2.36	2.90	2.08	2.04
7. Food	0.24	0.81	0.19	-0.62	0.06	0.08	-0.55	1.37
8. Tobacco	-2.09	-0.63	-3.37	-1.82	-1.21	0.22	-1.66	-2.69
9. Textile	-0.45	1.43	-0.86	-2.82	-0.74	1.21	-2.43	-0.48
10. Apparel	-0.89	1.00	-0.69	-4.56	0.01	1.92	-1.20	-0.67
11. Lumber and Wood	0.62	1.51	0.19	0.01	1.26	2.44	0.14	1.65
12. Furniture	1.51	3.33	1.90	-2.46	1.42	3.30	0.33	0.52
13. Paper	0.58	2.11	0.03	-0.88	0.95	1.77	0.18	1.19
14. Printing	1.64	2.04	2.33	-0.54	2.18	0.70	3.98	0.88
15. Chemicals	1.29	2.22	1.25	-0.22	1.22	1.63	1.03	0.91
16. Petroleum Refining	0.03	1.80	-0.58	-1.72	-0.69	-0.38	-0.86	-0.87
17. Rubber and Plastics	3.44	5.65	2.83	0.96	2.84	5.55	0.71	2.76
18. Leather	-3.04	-1.79	-2.55	-6.21	-3.03	-0.35	-5.32	-2.69
19. Stone, Clay and Glass	0.27	2.60	-0.02	-3.11	0.36	2.05	-0.95	0.30

TABLE 8 (CONT'D)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	0.27	2.72	-0.30	-2.69	-0.70	1.97	-3.02	-0.32
21. Fabricated Metals	1.38	3.92	0.43	-0.94	0.81	2.50	-0.75	1.25
22. Non-elec. Machinery	2.58	4.13	2.51	0.09	1.44	3.32	0.26	0.77
23. Electrical Machinery	0.78	3.37	0.24	-2.53	1.35	2.76	0.92	-0.15
24. Motor Vehicles	4.03	8.56	1.53	1.60	1.72	3.57	-0.32	2.90
25. Other Trans. Equip.	1.09	1.80	1.78	-1.61	0.05	0.42	1.88	-4.49
26. Misc. Manufacturing	1.46	2.67	1.42	-0.53	1.42	2.61	1.60	-1.00
27. Trans. and Warehouse	1.95	1.50	1.98	2.65	1.48	1.20	0.82	3.37
28. Communications	2.30	3.54	2.43	-0.12	1.98	3.19	0.93	2.15
29. Electric Utilities	3.03	3.44	3.39	1.57	1.27	1.91	1.46	-0.22
30. Gas Utilities	2.40	1.07	2.91	3.60	0.07	0.67	-0.46	0.16
31. Trade	2.48	3.43	2.40	1.00	2.00	2.07	1.92	2.04
32. Finance, Ins. and Real Estate	3.42	4.76	3.74	0.44	3.11	3.63	3.18	2.07
33. Other Services	4.45	4.77	5.00	2.72	4.30	3.91	4.67	4.20
Average	1.31	2.46	1.31	-0.64	0.80	1.73	0.24	0.42

TABLE 9

GROWTH OF INTERMEDIATE INPUTS IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	4.08	4.60	4.64	1.97	0.73	3.30	-0.68	-0.66
2. Metal Mining	3.93	7.64	2.01	1.70	-3.03	2.06	-9.35	1.80
3. Coal Mining	6.00	7.15	7.56	0.68	1.93	5.09	2.39	-4.48
4. Crude Pet. and Gas	7.89	8.85	9.03	3.83	0.05	1.63	-1.46	0.58
5. Non-met. Mining	3.10	6.83	2.00	-0.93	0.44	2.22	-1.19	0.86
6. Construction	2.47	5.17	2.35	-1.90	1.46	3.34	0.64	-0.04
7. Food	2.14	3.13	2.07	0.60	1.55	2.16	1.08	1.53
8. Tobacco	-0.04	1.76	-1.56	0.12	-0.60	-0.82	-1.00	0.64
9. Textile	2.25	5.86	1.19	-1.66	1.05	3.89	-0.71	-0.06
10. Apparel	1.94	5.42	1.15	-2.34	1.14	3.76	-1.04	1.34
11. Lumber and Wood	4.04	5.68	3.12	3.21	3.05	6.25	0.69	2.59
12. Furniture	3.43	6.43	3.50	-1.88	2.68	5.29	0.82	2.20
13. Paper	3.32	5.25	2.55	1.69	2.75	4.63	1.78	1.62
14. Printing	3.36	4.66	4.49	-1.29	2.28	3.81	2.11	0.01
15. Chemicals	3.94	5.86	3.79	0.96	2.82	5.57	1.16	1.66
16. Petroleum Refining	2.26	6.03	-0.25	1.19	1.47	2.74	0.85	0.64
17. Rubber and Plastics	5.75	9.50	4.13	2.78	4.35	7.85	1.96	3.46
18. Leather	-1.39	1.31	-1.30	-6.19	-2.10	0.26	-3.22	-3.74
19. Stone, Clay and Glass	2.19	5.46	1.59	-2.11	1.41	4.26	-0.29	0.15

TABLE 9 (CONT'D)

	Canada				United States			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	2.81	5.07	1.58	1.57	0.79	4.73	-2.38	0.84
21. Fabricated Metals	2.86	6.78	1.66	-1.27	1.89	4.82	-0.27	1.46
22. Non-elec. Machinery	6.52	8.47	3.60	9.42	3.87	6.57	1.15	5.08
23. Electrical Machinery	4.63	6.51	3.08	4.73	3.66	5.70	1.26	5.32
24. Motor Vehicles	7.27	12.71	3.90	5.14	3.85	6.88	1.54	3.60
25. Other Trans. Equip.	3.96	5.42	3.15	3.20	1.26	2.68	1.86	-2.45
26. Misc. Manufacturing	2.79	5.52	2.19	-0.60	2.86	4.41	2.27	1.46
27. Trans. and Warehouse	4.07	6.16	3.29	2.18	3.54	4.99	2.49	3.32
28. Communications	6.51	6.17	7.63	4.68	6.18	5.25	8.53	2.73
29. Electric Utilities	6.32	7.86	3.95	8.80	4.40	7.02	3.30	2.28
30. Gas Utilities	3.65	3.10	3.14	5.67	-0.56	4.50	-1.87	-6.43
31. Trade	4.23	4.88	3.84	3.97	3.85	6.23	2.53	2.58
32. Finance, Ins. and Real Estate	5.86	7.13	6.31	2.71	4.27	4.31	4.77	3.15
33. Other Services	5.39	5.81	5.71	3.98	5.59	7.13	5.23	3.72
Average	3.86	6.01	3.18	1.65	2.09	4.32	0.76	1.11

TABLE 10

GROWTH OF CAPITAL QUALITY IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	1.04	3.87	0.50	-2.64	0.75	1.56	0.40	0.13
2. Metal Mining	-0.56	-0.98	-0.37	-0.25	0.07	0.24	0.09	-0.27
3. Coal Mining	-0.37	-0.66	-0.06	-0.53	-0.18	0.38	-0.52	-0.41
4. Crude Pet. and Gas	-0.09	-0.09	-0.02	-0.25	0.14	0.31	0.15	-0.17
5. Non-met. Mining	-0.32	-0.31	-0.26	-0.46	-0.02	0.22	-0.21	-0.02
6. Construction	0.90	1.48	0.51	0.75	-0.03	0.22	-0.13	-0.23
7. Food	0.34	0.57	0.17	0.31	0.50	0.88	0.40	0.04
8. Tobacco	0.30	0.48	0.24	0.14	0.04	0.15	-0.03	0.00
9. Textile	0.04	0.49	-0.32	0.06	0.61	1.58	0.19	-0.13
10. Apparel	0.11	0.77	-0.36	-0.02	0.33	0.95	0.02	-0.07
11. Lumber and Wood	0.57	0.98	0.02	1.05	0.22	0.44	0.18	-0.05
12. Furniture	0.44	0.31	-0.28	2.20	0.60	1.38	0.26	0.01
13. Paper	0.15	0.44	-0.12	0.22	0.51	0.81	0.48	0.08
14. Printing	0.10	0.11	0.23	-0.17	0.27	0.36	0.31	0.04
15. Chemicals	0.48	0.89	0.39	0.01	0.48	0.93	0.31	0.07
16. Petroleum Refining	3.92	6.16	3.64	0.69	0.97	1.25	0.79	0.88
17. Rubber and Plastics	0.77	0.64	0.65	1.26	0.21	0.35	0.12	0.17
18. Leather	0.00	1.07	-0.65	-0.42	0.40	0.95	0.14	0.03
19. Stone, Clay and Glass	0.40	0.50	0.34	0.36	0.61	1.16	0.57	-0.23

TABLE 10 (CONT'D)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	0.67	0.85	0.51	0.71	0.67	1.38	0.50	-0.16
21. Fabricated Metals	0.34	0.98	-0.20	0.42	0.41	0.80	0.29	-0.03
22. Non-elec. Machinery	0.37	0.51	0.23	0.40	0.49	0.59	0.73	-0.23
23. Electrical Machinery	0.06	0.55	0.17	-1.00	0.94	1.77	0.67	0.10
24. Motor Vehicles	1.57	1.01	1.84	1.94	0.66	1.18	0.85	-0.62
25. Other Trans. Equip.	-0.30	-0.52	-0.30	0.06	0.44	0.56	0.57	-0.02
26. Misc. Manufacturing	0.22	0.26	0.09	0.43	0.34	0.36	0.26	0.47
27. Trans. and Warehouse	0.23	-0.07	0.23	0.76	0.84	1.18	0.70	0.52
28. Communications	0.09	-0.02	0.16	0.10	0.51	1.15	0.23	0.01
29. Electric Utilities	0.43	0.58	0.50	0.05	0.42	0.59	0.41	0.17
30. Gas Utilities	0.42	0.34	0.52	0.32	0.28	-0.03	0.43	0.49
31. Trade	0.68	1.10	-0.05	1.51	1.07	1.83	0.83	0.26
32. Finance, Ins. and Real Estate	1.70	1.26	2.78	0.15	1.15	1.36	1.24	0.61
33. Other Services	2.91	2.84	3.68	1.35	0.85	1.79	0.49	0.00
Average	0.53	0.80	0.44	0.29	0.47	0.87	0.36	0.04

TABLE 11

GROWTH OF LABOUR QUALITY IN CANADA AND THE UNITED STATES (%)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
1. Agric., For. and Fisheries	0.50	0.41	0.61	0.41	0.93	1.22	0.67	1.02
2. Metal Mining	0.19	0.31	0.19	0.01	0.53	0.60	0.65	0.18
3. Coal Mining	0.39	0.79	0.34	-0.18	0.43	0.60	-0.05	1.16
4. Crude Pet. and Gas	0.25	0.06	0.28	0.52	0.36	-0.12	0.89	0.05
5. Non-met. Mining	0.37	0.55	0.26	0.30	0.46	0.77	0.03	0.85
6. Construction	0.37	0.44	0.41	0.19	0.33	0.18	0.25	0.74
7. Food	0.25	0.25	0.18	0.37	0.40	0.30	0.30	0.80
8. Tobacco	0.71	0.80	0.60	0.78	0.81	0.90	0.61	1.10
9. Textile	0.42	0.33	0.52	0.36	0.36	0.30	0.19	0.82
10. Apparel	0.06	0.01	0.00	0.26	0.52	0.47	0.23	1.22
11. Lumber and Wood	0.29	0.50	0.20	0.12	0.56	0.72	0.22	0.99
12. Furniture	0.20	0.20	0.16	0.30	0.38	0.73	-0.09	0.76
13. Paper	0.29	0.24	0.28	0.42	0.51	0.39	0.47	0.77
14. Printing	0.13	0.18	0.00	0.35	0.49	0.03	0.75	0.73
15. Chemicals	0.29	0.25	0.17	0.60	0.51	0.16	0.60	0.94
16. Petroleum Refining	0.32	0.31	0.16	0.67	0.23	0.39	0.02	0.42
17. Rubber and Plastics	0.17	0.02	0.23	0.30	0.27	0.33	-0.05	0.87
18. Leather	0.09	-0.08	0.07	0.42	0.41	0.99	-0.50	1.37
19. Stone, Clay and Glass	0.25	0.35	0.18	0.24	0.38	0.63	0.00	0.76

TABLE 11 (CONT'D)

	CANADA				UNITED STATES			
	1961-95	1961-73	1973-88	1988-95	1961-95	1961-73	1973-88	1988-95
20. Primary Metals	0.24	0.28	0.21	0.23	0.36	0.34	0.26	0.59
21. Fabricated Metals	0.26	0.29	0.14	0.46	0.30	0.11	0.16	0.94
22. Non-elec. Machinery	0.25	0.34	0.14	0.32	0.44	0.23	0.41	0.87
23. Electrical Machinery	0.30	0.15	0.25	0.66	0.50	0.20	0.50	0.99
24. Motor Vehicles	0.17	0.19	0.06	0.38	0.42	0.31	0.32	0.83
25. Other Trans. Equip.	0.26	0.41	0.18	0.18	0.41	0.36	0.39	0.54
26. Misc. Manufacturing	0.23	0.20	0.14	0.45	0.58	0.50	0.50	0.87
27. Trans. and Warehouse	0.36	0.44	0.25	0.46	0.13	0.35	-0.13	0.32
28. Communications	0.35	0.52	0.31	0.14	0.57	0.21	0.53	1.25
29. Electric Utilities	0.45	0.59	0.38	0.33	0.26	0.07	0.14	0.85
30. Gas Utilities	0.27	0.34	0.27	0.14	0.31	0.25	0.28	0.47
31. Trade	0.24	0.40	0.08	0.32	0.42	0.42	0.27	0.71
32. Finance, Ins. and Real Estate	0.11	-0.05	0.09	0.41	0.45	0.24	0.23	1.30
33. Other Services	0.66	0.87	0.45	0.74	0.49	0.45	0.63	0.28
Average	0.29	0.33	0.24	0.35	0.44	0.41	0.29	0.80

CONCLUSIONS

IN THIS CHAPTER, WE APPLIED A SIMILAR METHODOLOGY to provide a consistent international comparison of the patterns of growth in Canadian and U.S. industries over the period 1961-95 and three sub-periods (1961-73, 1973-88, and 1988-95). The main findings are as follows: (1) Average annual growth rates of output in Canada were higher than in the United States in almost all industries before 1988. After 1988, output growth in Canada was slower than in the United States. (2) There was a substantial catch-up by Canadian industries to the productivity levels of U.S. industries during the period 1961-73. After 1973, productivity in Canadian industries grew at a rate similar to that of their U.S. counterparts. Over 1988-95, productivity in Canada grew at a slower rate than in the United States in 20 of 33 industries. (3) The dominant sources of output growth are the contributions of capital, labour, and intermediate inputs, with productivity growth responsible for about 20 percent of output growth in both countries during the entire period. (4) An interesting feature of Canadian economic growth has been the high growth of intermediate inputs. (5) The rise in capital and labour quality caused by composition changes contributes to the economic growth of both countries, in proportions varying from a seventh to a quarter of output growth.

ENDNOTES

1 In this study, we examine 'total factor productivity' as opposed to labour productivity. That is, we consider all inputs — capital, labour, and intermediate goods.
2 The definition of the term 'quality' is given in section entitled *Methodology* below.
3 For an approach that does not assume Hicks neutrality and that estimates productivity growth econometrically, see Chapter 7 of Jorgenson, Gollop and Fraumeni (1987).
4 The data on intermediate inputs comes from the input-output tables, and we work at the level corresponding to $r = 33$ for the United States.
5 In this study, we use official data produced by the two governments. There are serious discussions regarding the accuracy of these statistics, in particular for the hard-to-measure service sector. See, for example, Triplett and Bosworth (2000). Our estimates should be read with this caveat in mind.
6 The concordance between the 122 industries of the Canadian business sector and the 33 industries of its U.S. counterpart is presented in Appendix A of this chapter.

7 The projections made by the Office of Employment of the BLS provided the time series of the I-O tables, as well as industry output and prices at the three-digit level of the Standard Industrial Classification (SIC, 1987 revision). Some of these data are available at ftp://ftp.bls.gov/pub/. The 185 sectors were aggregated to 35 sectors for the United States. The data in Jorgenson and Wilcoxen (1990) are based on the old SIC classifications and we mapped the two series in 1977. We extrapolated the I-O table to 1996 using industry output data for that year.

8 Details on the measurement of labour input are found, respectively, in Appendix C for the United States and in Appendix F for Canada, in Jorgenson and Lee (2001).

9 There is a slight difference in the educational attainment categories between Canada and the United States. Because of changes in the definition of educational attainment used for the Labour Force Survey of 1990, educational attainment is aggregated into four categories for Canada to ensure consistency over time. For the United States, there are six education categories. The difference in the number of categories is expected to have little effect on our estimates of labour input and labour quality.

10 Self-employed and unpaid family workers are combined into a single category in the United States. They are treated as two separate categories in Canada. Labour compensation for self-employed workers in Canada was estimated using the wage rates of paid workers, while labour compensation for unpaid family workers was ignored. Compensation in the U.S. data is estimated as a residual of non-corporate value added less a capital income calculated to equate the rates of return of corporate and non-corporate capital.

11 The Census provides detailed information (age, education, hours worked, industry of employment, wages, etc.) for a 1 percent sample. The U.S. Department of Labor conducts annual surveys with similar detail for a smaller sample. These data are used to estimate the characteristics of the entire labour force on a time series basis.

12 Details on the measurement of capital inputs are provided in Appendix A for the United States and in Appendix E for Canada, in Jorgenson and Lee (2001).

13 For the U.S. data, see "Gross Product by Industry" in *Survey of Current Business*, November 1997.

14 Gross output over time is affected by the degree of change in industrial organisation — that is, a vertical consolidation will reduce total gross output even if there are no physical changes. The comparison of output growth is misleading to the extent that these changes are different in the two countries. However, gross output growth rates are roughly in line with total value added (GDP) reported in section entitled *Private Business Sector*; hence, this should not be a major concern.

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APPENDIX A

CONCORDANCE BETWEEN CANADIAN AND U.S. INDUSTRIES

TABLE A1

CONCORDANCE BETWEEN CANADIAN AND U.S. INDUSTRIES

CANADA: 122 INDUSTRIES	UNITED STATES: 33 INDUSTRIES	ABBREVIATION
1-2	1. Agriculture, Forestry, and Fisheries	1. Agric., For. and Fisheries
4-6, 13	2. Metal Mining	2. Metal Mining
10	3. Coal Mining	3. Coal Mining
11	4. Crude Petroleum and Natural Gas	4. Crude Pet. and Gas
7-9, 12	5. Non-metallic Mining	5. Non-met. Mining
98	6. Construction	6. Construction
14-24	7. Food and Kindred Products	7. Food
25	8. Tobacco Products	8. Tobacco
29-32	9. Textile Mill Products	9. Textile
33	10. Apparel and Other Textiles	10. Apparel
3, 34-38	11. Lumber and Wood	11. Lumber and Wood
39-41	12. Furniture and Fixtures	12. Furniture
42-45	13. Paper and Allied Products	13. Paper
46-47	14. Printing and Publishing	14. Printing

TABLE A1 (CONT'D)

CANADA: 122 INDUSTRIES	UNITED STATES: 33 INDUSTRIES	ABBREVIATION
87-93	15. Chemicals	15. Chemicals
86	16. Petroleum and Coal Products	16. Petroleum Refining
26-27	17. Rubber and Plastics	17. Rubber and Plastics
28	18. Leather Products	18. Leather
80-85	19. Stone, Clay, and Glass	19. Stone, Clay and Glass
48-54	20. Primary Metals	20. Primary Metals
55-59, 62	21. Fabricated Metals	21. Fabricated Metals
60-61, 63-65, 78	22. Non-Electrical Machinery	22. Non-elec. Machinery
73-77, 79	23. Electrical Machinery	23. Electrical Machinery
67-69	24. Motor Vehicles	24. Motor Vehicles
66,70-72	25. Transportation Equipment and Ordnance	25. Other Trans. Equip.
94-97	26. Miscellaneous Manufacturing	26. Misc. Manufacturing
99-105	27. Other Transportation	27. Trans. and Warehouse
106-107	28. Communications	28. Communications
109	29. Electric Utilities	29. Electric Utilities
110	30. Gas Utilities	30. Gas Utilities
112-113	31. Trade	31. Trade
114-115	32. Finance, Insurance, Real Estate	32. Finance, Ins., Real Estate
111, 116-122	33. Other Services	33. Other Services
108	Not Allocated	

APPENDIX B

SOURCES OF OUTPUT GROWTH BASED ON THE CAPITAL STOCK DATA FROM STATISTICS CANADA'S KLEMS DATABASE

STATISTICS CANADA'S ESTIMATES OF PRODUCTIVITY GROWTH are based on capital stock data, using a modified double-declining-balance method. For comparison purposes, Table B1 presents the sources of output growth for the private business sector in Canada, using these capital stock data. Comparing Table B1 and Table 3, we find that the contributions of capital input were lower than those based on capital stock estimates that are comparable to the BLS estimates. As a result, productivity growth estimates were higher using the capital stock estimates based on a modified double-declining-balance method. There is a gradual increase in the differences between these two productivity growth estimates, from 0.06 percent over 1961-73 to 0.15 percent over 1973-88 and 0.24 percent over 1988-95.

TABLE B1

SOURCES OF OUTPUT GROWTH IN THE PRIVATE BUSINESS SECTOR (%), BASED ON CAPITAL STOCK DATA FROM STATISTICS CANADA'S KLEMS DATABASE

	CANADA			
	1961-95	1961-73	1973-88	1988-95
Value Added	3.71	5.56	3.27	1.48
Contribution of Capital Stock	0.68	0.85	0.73	0.27
Contribution of Capital Quality	0.33	0.38	0.33	0.22
Contribution of Hours Worked	1.07	1.29	1.30	0.22
Contribution of Labour Quality	0.33	0.47	0.19	0.38
Productivity Growth	1.30	2.58	0.72	0.39

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3

Productivity Levels and International Competitiveness Between Canada and the United States

INTRODUCTION

THE PURPOSE OF THIS STUDY is to compare total factor productivity (TFP) levels and international competitiveness between 33 Canadian and U.S. industries. To carry out such comparisons, we first need to construct purchasing power parities (PPPs) for output and inputs by industry. We use bilateral Canada-U.S. commodity price data to construct PPPs for output and intermediate inputs, and estimate capital input PPPs based on the relative prices of investment goods, taking into account the flow of capital services per unit of capital stock. We then use hourly labour compensation rates, disaggregated by different worker types in the two countries, to estimate labour input PPPs. These PPPs take into account differences in the composition of the output and inputs of the industry under consideration between Canada and the United States, thereby allowing inter-country comparisons of both prices and quantities of output and inputs.

As in Jorgenson and Nishimizu's (1978) comparison between Japan and the United States, we use a translog production function originally introduced by Christensen, Jorgenson and Lau (1971, 1973) to estimate relative TFP levels in Canada and the United States. This framework was used extensively by Jorgenson and his associates, including Jorgenson, Kuroda and Nishimizu (1987), Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999). Following that tradition, relative TFP levels can be assumed to reflect differences in technology levels since the quality of inputs is already taken into account in this framework.

Based on a common framework using comparable data sets for Canada and the United States,[1] our results show that in 1995, 23 of 33 Canadian industries had lower TFP levels than their U.S. counterparts.[2] Our results also suggest that the relative TFP level is an important element of international competitiveness across industries. In fact, Canadian industries with higher TFP levels than their U.S. counterparts tend to be more competitive in terms of relative output prices. Over time, however, movements in the exchange rate appear to be the most significant factor behind international competitiveness. From 1988 to 1995, the falling exchange rate helped 9 Canadian industries become more competitive than their U.S. counterparts. In addition, movements in the exchange rate coincided with movements in the relative output prices of the private business sector in the two countries over the 1961-95 period. Focusing on a more recent period, that between 1976 and 1995, Canada's private business sector saw its competitiveness improve relative to that of the U.S. business sector, even though its TFP performance was not improving — although a slight rebound has occurred in that respect since 1993.

The remaining sections of the chapter are organized as follows. In the section entitled *Purchasing Power Parities for Output and Inputs*, we construct PPPs for output and inputs; the two next sections, entitled *Relative Productivity Levels* and *Competitiveness in Canadian and U.S. Industries*, are devoted to a comparison of TFP levels and international competitiveness between Canadian and U.S. industries. In the section entitled *Canada-U.S. Differences in Productivity and International Competitiveness in the Private Business Sector*, we discuss the evolution of TFP and competitiveness in the Canadian and U.S. private business sectors. We conclude our study in the last section.

PURCHASING POWER PARITIES FOR OUTPUT AND INPUTS

IN THIS SECTION, WE DISCUSS the data and methodology used in constructing Canada-U.S. bilateral PPPs for output and inputs in 33 industries. In this context, it is useful to keep in mind that the value of output is defined from the producer's point of view and the value of inputs, from the producer-purchaser's standpoint. This has implications for constructing PPPs, as will be seen later.

First, we aggregate the 1992 Canadian and U.S. input-output tables[3] into 249 common commodity groups and 33 industries.[4] We then match 201 commodity PPPs[5] at purchasers' prices with commodities in the I-O tables. Among the remaining 48 commodities in the I-O tables, we first identify 26 that have close substitutes among the 201 commodities already matched, and then apply to them the PPPs of their close substitutes. For the remaining 22 commodities, we use the 1993 market exchange rate. These commodities are mainly primary goods (such as grain, wheat, copper, steel, and precious metals) that are heavily traded in

North American or world markets. The 249 PPPs and the I-O tables are used to develop PPPs for output and inputs other than labour.[6]

PURCHASING POWER PARITIES FOR OUTPUT

THE OUTPUT PPP IS DEFINED AS THE RATIO of the amount of Canadian dollars received by Canadian producers for output sold in Canada, to the amount of U.S. dollars received by U.S. producers from the sale of the same amount of output in the United States. Thus output PPPs are at producers' prices, implying that we first need to convert commodity PPPs at purchasers' prices, $EPPP_j$, into commodity PPPs at producers' prices, PPP_j, by 'peeling off' tax and distribution margins (the indirect commodity tax margin and the transportation and trade margins), using the I-O tables of both countries.[7]

We then proceed to construct output PPPs for each industry. The output PPP of industry i is obtained by aggregating 249 commodity PPPs in translog form, using nominal shares in the commodity mix as weights for industry i:

$$(1) \quad \ln(PPP_i^Q) = \sum_{j=1}^{249} 1/2 \left[\upsilon_{i,j}^Q (Can) + \upsilon_{i,j}^Q (US) \right] \cdot \ln(PPP_j),$$

where $\upsilon_{i,j}^Q(S)$ is the value share of commodity j in industry i in country S, estimated from the *make* matrices of the I-O tables.

PURCHASING POWER PARITIES FOR INTERMEDIATE INPUTS

INTERMEDIATE INPUTS INCLUDE ENERGY, materials, and purchased services. Their PPPs are computed in the same manner as output PPPs, but they are based on commodity PPPs at purchasers' prices, which include tax, transportation, and trade margins. With this in mind, the PPP for intermediate inputs in industry i is defined as the translog aggregate of the 249 commodity PPPs:

$$(2) \quad \ln(PPP_i^M) = \sum_{j=1}^{249} 1/2 \left[\upsilon_{i,j}^M (Can) + \upsilon_{i,j}^M (US) \right] \cdot \ln(EPPP_j),$$

where $\upsilon_{i,j}^M(S)$ is the value share of goods (or services) of type j that are used as intermediate inputs in industry i in country S, estimated from the *use* matrices of the I-O tables. Here, $EPPP_j$ is the PPP at purchasers' prices for commodity j as defined earlier.

PURCHASING POWER PARITIES FOR CAPITAL INPUT

CAPITAL INPUT IS BROKEN DOWN here into four asset types — machinery and equipment (M&E), non-residential structures, inventories, and land. However, the price data available only allow us to construct investment PPPs for M&E and structures. Following Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999), we aggregate 249 commodity PPPs to construct investment PPPs for new investment type k (M&E or structures) in industry i from the purchasers' standpoint:

$$(3) \quad \ln(PPP^{I}_{i,k}) = \sum_{j=1}^{249} 1/2 \left[v^{I}_{i,k,j}(Can) + v^{I}_{i,k,j}(US) \right] \cdot \ln(EPPP_{j}),$$

where $v^{I}_{i,k,j}(S)$ is the value share of investment good j of type k in industry i, estimated from the *investment flow* matrices of the I-O tables.

We then derive a capital input PPP for each type (M&E and structures) in industry i by multiplying the ratio of each asset type's rental price for Canada relative to the United States by its corresponding investment PPP,

$$(4) \quad PPP^{K}_{i,k} = \left(\frac{P^{K}_{i,k}(Can) / P^{I}_{i,k}(Can)}{P^{K}_{i,k}(US) / P^{I}_{i,k}(US)} \right) PPP^{I}_{i,k},$$

where $P^{K}_{i,k}(S)$ is the capital input price of asset type k in country S, while $P^{I}_{i,k}(S)$ is the investment price index for that asset type. For each asset type, the ratio of the capital input price to the investment price index is the rental price of capital input of this asset type. The rental price of capital input is estimated by taking account of the rate of return on capital, economic depreciation rates, and various tax parameters in each country. Thus, in deriving capital input PPPs, we implicitly assume that the relative efficiency of new capital goods in a given industry is the same in both countries. However, the decline in the efficiency of capital input for each component is estimated separately for each country.

We assume that the capital input PPP for land is the same as that for structures. Furthermore, we assume that the capital input PPP for inventories is the same as the weighted average of capital input PPPs for M&E, structures and land. The total capital input PPPs in this study are then derived by aggregating individual capital input PPPs across p types of capital input (M&E, structures, land, and inventories), using the average compensation of each type of capital input in the two countries as weights:

$$(5) \quad \ln(PPP^{K}_{i}) = \sum_{k=1}^{p} 1/2 \left[v^{K}_{i,k}(Can) + v^{K}_{i,k}(US) \right] \cdot \ln(PPP^{K}_{i,k}),$$

where $v^{K}_{i,k}(S)$ is the capital compensation share of type k capital in industry i in country S.

PURCHASING POWER PARITIES FOR LABOUR INPUT

FOR EACH OF THE 33 INDUSTRIES, labour inputs in Canada and the United States is matched by sex, employment status, age, and education, as shown in Table 1. We estimate the labour input PPP for industry i by aggregating the ratio of hourly labour compensation rates between the two countries over q types (112) of labour:

$$(6) \qquad \ln(PPP_i^L) = \sum_{l=1}^{q} \left\{ 1/2 \left[v_{i,l}^L(Can) + v_{i,l}^L(US) \right] \cdot \ln \left[\frac{P_{i,l}^L(Can)}{P_{i,l}^L(US)} \right] \right\},$$

where $P_{i,l}^L(S)$ is the average labour compensation per hour of type l worker in industry i in country S, and $v_{i,l}^L(S)$ is the total labour compensation share for that worker type.

SUMMARY OF PURCHASING POWER PARITIES BETWEEN CANADA AND THE UNITED STATES, 1993

THE PPPS FOR OUTPUT AND THREE TYPES OF INPUTS IN 1993 are reported in Table 2.[8] The output PPPs are generally in line with the exchange rate (1.29 in 1993) for most industries. However, for coal mining, tobacco, and electric utilities, they are on the lower side.

TABLE 1

CLASSIFICATION OF THE CANADIAN AND U.S. WORKFORCE

WORKER CHARACTERISTICS	NUMBER OF CATEGORIES	TYPE
Sex	2	Female; Male
Employment Category	2	Paid Employees; Self-employed[1]
Age	7	16-17;[2] 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	0-8 Years Grade School; Some or Completed High School; Some or Completed Post-Secondary School; University or Higher

Notes: [1] U.S. self-employed includes unpaid workers.
[2] That age group is 15-17 for Canada.

TABLE 2

PURCHASING POWER PARITIES BY INDUSTRY, 1993 (U.S. = 1.00)

INDUSTRY	OUTPUT	CAPITAL INPUT	LABOUR INPUT	INTERMEDIATE INPUTS
1. Agriculture, Forestry and Fisheries	1.35	1.93	0.62	1.35
2. Metal Mining	1.29	1.70	1.06	1.27
3. Coal Mining	0.88	0.99	0.88	1.29
4. Crude Petroleum and Gas	1.45	1.09	1.02	1.26
5. Non-metallic Mining	1.35	1.82	1.04	1.29
6. Construction	1.13	2.08	1.13	1.34
7. Food	1.42	2.13	1.11	1.36
8. Tobacco	0.74	2.23	1.05	1.57
9. Textile	1.46	2.36	1.06	1.35
10. Apparel	1.34	2.29	0.96	1.38
11. Lumber and Wood	1.25	1.88	1.21	1.24
12. Furniture	1.36	2.41	0.93	1.35
13. Paper	1.55	0.75	1.16	1.30
14. Printing	1.52	2.45	1.12	1.35
15. Chemicals	1.28	1.19	0.81	1.32
16. Petroleum Refining	1.13	0.47	0.99	1.29
17. Rubber and Plastics	1.58	2.73	1.02	1.31
18. Leather	1.32	0.83	1.06	1.27
19. Stone, Clay and Glass	1.41	2.08	1.01	1.32
20. Primary Metals	1.28	1.10	1.07	1.26
21. Fabricated Metals	1.40	1.85	0.89	1.29
22. Industrial Machinery	1.30	2.55	0.85	1.28
23. Electrical Machinery	1.17	1.70	0.92	1.23
24. Motor Vehicles	1.23	3.59	0.76	1.35
25. Other Transportation Equip.	1.35	2.19	0.97	1.31
26. Miscellaneous Manufacturing	1.29	2.40	0.80	1.30
27. Transportation and Warehousing	1.33	1.60	0.85	1.29
28. Communications	1.18	1.23	0.93	1.23
29. Electric Utilities	0.90	1.15	1.12	1.19
30. Gas Utilities	1.30	1.95	0.86	1.26
31. Trade	1.19	1.60	1.05	1.29
32. Finance, Insurance and Real Estate	1.32	2.05	0.81	1.24
33. Other Services	1.08	0.37	0.98	1.25
Private Business Sector	1.22[1]	1.23	0.96	

Note: [1] For value added from Statistics Canada's Canada-U.S. GDP purchasing power parity.

Capital input PPPs are highly variable across industries. These variations stem from differences in the rental prices of capital input between the two countries since capital investment prices are generally comparable. For instance, the rental prices of capital input in the motor vehicles, rubber and plastics, and industrial machinery industries are higher in Canada than in the United States, while the opposite is true in the paper and allied products, petroleum refining, and other services industries. The higher rental price of capital input in other services in the United States is mainly due to a higher rental price in private education and legal services in that country than in Canada. A close examination reveals that the substantial differences in the rental prices of capital input noted between Canada and the United States are attributable to large differences in the capital compensation figures from the two countries' I-O tables relative to their respective capital stocks.

With respect to the labour input PPPs, we first observe that variations across industries are very small. In addition, labour input PPPs are below unity in 17 industries, which is significantly below the exchange rate.

Finally, intermediate input PPPs are fairly constant across industries and more or less equal to the exchange rate in all industries except tobacco. The Canadian tobacco industry pays a higher price for intermediate inputs than does its U.S. counterpart, mainly because of the difference in the taxation on semi-finished tobacco products between the two countries.

RELATIVE PRODUCTIVITY LEVELS

BASED ON THE PPPS CONSTRUCTED ABOVE, we estimate relative TFP levels between Canada and the United States for 33 industries.[9] As in Jorgenson and Nishimizu's (1978) comparison between Japan and the United States, our theoretical framework for this comparison is based on a translog production function originally introduced by Christensen, Jorgenson, and Lau (1971, 1973). Here, output is a translog function of capital input, labour input, and intermediate inputs, a dummy variable equal to one for Canada and zero for the United States, and time as an index of technology for each industry. However, as did Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999), we find that it is more convenient to work with the dual price function of output to analyse international competitiveness and relative TFP levels. The dual price function is derived from the production function under competitive conditions. The price function for the ith industry can be represented as:

$$(7) \quad \ln P_i = \ln P_i^{X'} \alpha_i^X + \alpha_i^t t + \alpha_i^D D + 1/2 \ln P_i^{X'} \beta_i^{XX} \ln P_i^X + \ln P_i^{X'} \beta_i^{Xt} t$$
$$+ \ln P_i^{X'} \beta_i^{XD} D + 1/2 \beta_i^{tt} t_2 + \beta_i^{tD} t D + 1/2 \beta_i^{DD} D_2,$$

where P_i is the output price of the ith industry; $\ln P_i^X$ denotes $\{\ln P_i^K \ln P_i^L \ln P_i^M\}$, a vector of logarithms of capital input price (P_i^K), the labour input price (P_i^L), and the intermediate input price (P_i^M) of the ith industry; t denotes time as an index of technology; and D is a dummy variable, equal to one for Canada and zero for the United States.

In this presentation, scalars $\{\alpha_i^t, \alpha_i^D, \beta_i^{tt}, \beta_i^{tD}, \beta_i^{DD}\}$, the vectors $\{\alpha_i^X, \beta_i^{Xt}, \beta_i^{XD}\}$, and the matrix $\{\beta_i^{XX}\}$ are constant parameters. However, these parameters differ among industries, reflecting differences among technologies. Within each industry, differences in technology among time periods are represented by time as an index of technology. Differences in technology between Canada and the United States are associated with the dummy variable.

Based on the above price function, Jorgenson and Kuroda (1995), and Kuroda and Nomura (1999) show that differences in the logarithms of the TFP levels between Canada and the United States, $\bar{v}_i^D$ can be expressed as the negative value of the differences between the logarithms of the output prices, less a weighted average of the differences between the logarithms of input prices,

$$(8)\quad \bar{v}_i^D = -\left\{\ln\left[\frac{P_i(Can)}{P_i(US)}\right] - \bar{v}_i^K \ln\left[\frac{P_i^K(Can)}{P_i^K(US)}\right] - \bar{v}_i^L \ln\left[\frac{P_i^L(Can)}{P_i^L(US)}\right] - \bar{v}_i^M \ln\left[\frac{P_i^M(Can)}{P_i^M(US)}\right]\right\},$$

where $\bar{v}_i^j = 1/2\left[v_i^j(Can) + v_i^j(US)\right]$, the average compensation share of input j in Canada and the United States for the ith industry. The price ratios in the above equation are the PPPs for output and inputs.

We first calculate 1993 relative TFP levels in Canada and the United States for 33 industries based on the estimated 1993 PPPs using Equation (8). We then use the TFP indices constructed by Gu and Ho (Jorgenson and Lee, 2001) to estimate relative TFP levels in other years. The estimated relative TFP levels by industry are reported in Table 3. In 1995, Canada was less productive than the United States in 23 of the 33 industries. In particular, Canada was much less productive in agriculture, forestry and fisheries; crude petroleum and gas; paper; printing; rubber and plastics; leather; stone, clay, and glass; fabricated metals; industrial machinery; and transportation and warehousing. On the other hand, in 1995 Canada was significantly more productive than the United States in coal mining, construction, tobacco, petroleum refining, electric utilities, and gas utilities.

To examine the trend in relative TFP levels in Canadian and U.S. industries, we estimated the variance of relative TFP levels by industry over the period 1961-95. As shown in Figure 1, the variance for all industries declined dramatically in the 1960s. After 1970, however, it remained fairly stable. This implies that TFP performance in Canada and the United States converged across industries during the 1960s. Indeed, in 19 of the 25 industries where Canada lagged behind the United States with respect to TFP levels in 1961, Canada improved its relative TFP performance from 1961 to 1973; the largest improvements occurred in those industries where TFP gaps were the widest (coal mining and communications). At the same time, Canada lost some of its relative TFP advantage in 2 industries (tobacco and petroleum refining) where that advantage was the largest in 1961. Between 1973 and 1988, the variance remained more or less steady. Over this period, some low-productivity Canadian industries caught up somewhat to their U.S. counterparts, but their relative gains were modest. At the same time, these gains were offset by U.S. industries catching up to highly productive Canadian industries (metal mining, petroleum refining, and both machinery industries). Over the 1988-95 period, the variance of the relative TFP gap between the two countries decreased. Most of the decline can be attributed to U.S. industries (such as metal mining, coal mining, and electrical machinery) catching up to, and in some instances surpassing, the TFP levels of Canadian industries. Meanwhile, most Canadian industries that were less productive than their U.S. counterparts either were unable to catch up to U.S. TFP levels or only made modest gains.

FIGURE 1

VARIANCE OF THE PRODUCTIVITY GAP (IN LOGS) AMONG INDUSTRIES

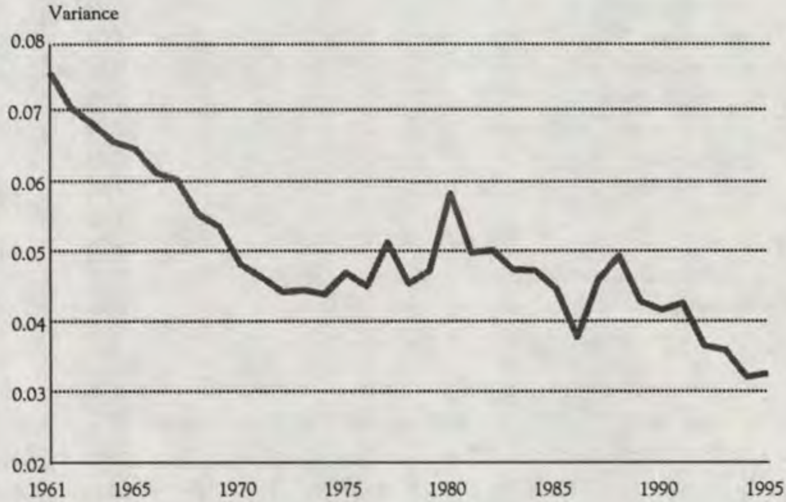


TABLE 3

TFP LEVELS IN CANADA RELATIVE TO THE UNITED STATES (U.S.= 1.00)

INDUSTRY	1961	1973	1988	1995
1. Agriculture, Forestry and Fisheries	0.87	0.98	0.89	0.83
2. Metal Mining	1.44	1.55	1.34	0.90
3. Coal Mining	0.77	1.15	1.50	1.16
4. Crude Petroleum and Gas	0.83	1.01	0.62	0.71
5. Non-metallic Mining	0.87	0.95	0.98	0.96
6. Construction	0.87	0.93	1.11	1.18
7. Food	1.15	1.13	0.97	0.96
8. Tobacco	1.75	1.60	2.06	2.06
9. Textile	1.09	1.23	1.03	0.98
10. Apparel	1.06	1.08	1.00	0.99
11. Lumber and Wood	0.79	0.90	0.91	1.01
12. Furniture	1.00	1.14	0.92	0.96
13. Paper	0.91	0.84	0.81	0.83
14. Printing	0.86	0.86	0.95	0.88
15. Chemicals	0.82	0.80	0.89	0.93
16. Petroleum Refining	1.39	1.30	1.09	1.15
17. Rubber and Plastics	0.85	0.91	0.86	0.85
18. Leather	0.71	0.82	0.85	0.83
19. Stone, Clay and Glass	0.86	1.01	0.95	0.87
20. Primary Metals	0.90	0.96	0.96	0.96
21. Fabricated Metals	0.81	0.85	0.84	0.84
22. Industrial Machinery	1.11	1.21	0.95	0.88
23. Electrical Machinery	1.26	1.31	1.15	0.98
24. Motor Vehicles	0.73	0.93	1.04	1.07
25. Other Transportation Equip.	1.02	0.98	0.89	0.98
26. Miscellaneous Manufacturing	1.09	1.07	0.90	0.92
27. Transportation and Warehousing	0.82	0.90	0.94	0.87
28. Communications	0.39	0.61	0.94	0.99
29. Electric Utilities	1.51	1.57	1.61	1.24
30. Gas Utilities	0.81	1.24	1.36	1.15
31. Trade	0.80	0.94	1.08	1.02
32. Finance, Insurance and Real Estate	1.29	1.15	0.92	1.09
33. Other Services	0.90	0.86	0.93	0.93

To give another perspective on this issue, we also examined the number of Canadian industries that were less productive than their U.S. counterparts. That number decreased from 20 in 1961 to 17 in 1973, as shown in Table 3. However, it rose to 21 in 1988 and 23 in 1995. Thus, the number of Canadian industries that were less productive than their U.S. counterparts has increased since 1973. These numbers provide a snapshot of performance in a given year, but they do not help to assess the improvement or deterioration of Canada's relative TFP performance over time.

We now turn to that issue. When we examine the evolution of relative TFP levels over time, the pervasiveness of the decline in Canada becomes evident. From 1961 to 1973, only 9 Canadian industries experienced a decline in TFP relative to their U.S. counterparts. However, that number rose to 16 between 1973 and 1988 and to 17 between 1988 and 1995. In summary, the deterioration of Canada's TFP levels relative to those of the United States has become more widespread across industries since 1973.

COMPETITIVENESS IN CANADIAN AND U.S. INDUSTRIES

THIS SECTION ASSESSES DIFFERENCES IN COMPETITIVENESS between Canadian and U.S. industries and links these differences to their relative TFP levels. Following Jorgenson and Kuroda (1995), we measure competitiveness by relative output prices, defined as output PPPs divided by the exchange rate ($CAN per $US).

To facilitate our analysis, we decompose relative output prices into relative TFP levels and relative capital, labour, and intermediate input prices. We rearrange Equation (8) and divide each price ratio by the exchange rate:

$$(9) \qquad \ln RP_i = -\bar{v}_i^D + \bar{v}_i^K \ln RP_i^K + \bar{v}_i^L \ln RP_i^L + \bar{v}_i^M \ln RP_i^M,$$

where RP_i is the relative price of output; $\bar{v}_i^D$ is the TFP gap between Canada and the United States for industry i; and RP_i^K, RP_i^L, and RP_i^M are the relative prices of capital, labour, and intermediate inputs, respectively.

The relative prices for output, for capital, labour, and intermediate inputs, and for relative TFP levels in 1995 are reported in Table 4. In 1995, more than half of Canadian industries had a lower relative output price than their U.S. counterparts.

Canada had higher capital input prices than the United States in 27 industries. In particular, Canadian capital input prices were substantially higher than U.S. prices in metal mining; textiles; apparel; furniture; paper; rubber and plastics; primary metals; motor vehicles; other transportation equipment; and miscellaneous manufacturing, in 1995. However, in some Canadian industries — such as coal mining; crude petroleum and natural gas; leather; and other services — capital input prices were lower than in the corresponding U.S. industries. As discussed earlier, it is helpful to keep in mind that differences in relative capital input prices reflect differences not only in capital investment prices but also in the rental prices of capital input.

TABLE 4

RELATIVE PRICES* AND TFP LEVELS BY INDUSTRY, 1995 (U.S. = 1.00)

INDUSTRY	OUTPUT	TFP	CAPITAL INPUT	LABOUR INPUT	INTERMEDIATE INPUTS
1. Agriculture, Forestry and Fisheries	1.13	0.83	1.76	0.56	1.03
2. Metal Mining	1.11	0.90	2.07	0.68	0.91
3. Coal Mining	0.67	1.16	0.70	0.66	0.99
4. Crude Petroleum and Gas	1.15	0.71	0.76	0.80	0.91
5. Non-metallic Mining	1.00	0.96	1.31	0.69	0.96
6. Construction	0.81	1.18	1.31	0.83	1.00
7. Food	1.05	0.96	1.21	0.78	1.03
8. Tobacco	0.61	2.06	1.74	0.69	1.29
9. Textile	1.10	0.98	3.26	0.77	1.05
10. Apparel	1.01	0.99	2.34	0.72	1.05
11. Lumber and Wood	0.96	1.01	1.20	0.98	0.92
12. Furniture	1.01	0.96	3.17	0.67	1.01
13. Paper	1.39	0.83	2.99	0.84	1.07
14. Printing	1.16	0.88	1.96	0.80	1.05
15. Chemicals	0.97	0.93	1.01	0.59	1.01
16. Petroleum Refining	0.85	1.15	1.21	0.75	0.99
17. Rubber and Plastics	1.23	0.85	2.20	0.79	1.04
18. Leather	0.99	0.83	0.48	0.72	1.01
19. Stone, Clay and Glass	1.06	0.87	1.49	0.71	0.95
20. Primary Metals	1.09	0.96	2.24	0.79	1.05
21. Fabricated Metals	1.08	0.84	1.54	0.66	0.98
22. Industrial Machinery	0.96	0.88	1.12	0.64	0.96
23. Electrical Machinery	0.90	0.98	1.35	0.64	0.92

TABLE 4 (CONT'D)

INDUSTRY	OUTPUT	TFP	CAPITAL INPUT	LABOUR INPUT	INTERMEDIATE INPUTS
24. Motor Vehicles	0.95	1.07	3.50	0.56	1.02
25. Other Transportation Equip.	1.01	0.98	2.70	0.70	1.02
26. Miscellaneous Manufacturing	0.97	0.92	2.48	0.55	1.00
27. Transportation and Warehousing	0.95	0.87	1.10	0.64	0.93
28. Communications	0.83	0.99	0.91	0.66	0.89
29. Electric Utilities	0.65	1.24	0.75	0.79	0.87
30. Gas Utilities	0.99	1.15	1.56	0.59	0.95
31. Trade	0.86	1.02	1.47	0.76	0.89
32. Finance, Insurance and Real Estate	0.88	1.09	1.51	0.64	0.87
33. Other Services	0.77	0.93	0.32	0.73	0.88

Note: * PPP rates divided by the exchange rate.

In contrast with the situation observed for capital input prices, all Canadian industries had an advantage over their U.S. counterparts in terms of labour costs, and the variations in relative labour input prices across industries were very small in 1995. As a result of these differences in labour costs, the industrial structures of the two countries are also different. Canadian industries are generally more labour-intensive, while U.S. industries tend to be more capital-intensive. This is evident when we compare capital intensity (the ratio of capital stock to hours worked) in the two countries. For instance, in 1993, capital intensity in Canada (capital stock PPP-based) was only 79 percent that of the United States.[10]

Finally, most Canadian industries paid almost the same price for their intermediate inputs as did their U.S. counterparts.

When examining the links between competitiveness, relative TFP levels, and relative input prices, a simple correlation among these variables is a good starting point for discussion. The correlation coefficient between relative output prices and relative TFP levels is -0.69 based on 1995 data, while in the case of capital, labour, and intermediate inputs, the coefficients stand at 0.47, 0.16, and 0.12, respectively. These coefficients indicate that variations in relative output prices across industries are strongly related to inter-industry differences in relative TFP levels.

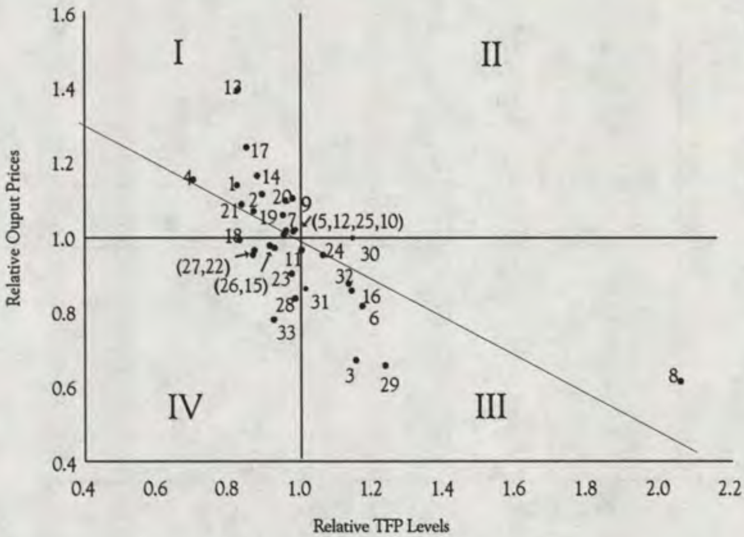
We summarise the relationship between output prices and TFP levels by plotting relative output prices against relative TFP levels for 1995 across industries in Canada and the United States, as shown in Figure 2. To better illustrate the relationship between competitiveness and relative TFP levels, we divide the figure into four quadrants. In quadrants I and II are found those Canadian industries which are less competitive than their U.S. counterparts, while quadrants III and IV show Canadian industries that are more competitive than their U.S. equivalents. At the same time, Canadian industries in quadrants II and III are more productive than their U.S. competitors, while relatively less productive industries in Canada are located in quadrants I and IV.

In 1995, 15 Canadian industries were less competitive and less productive than the corresponding U.S. industries (quadrant I). In 7 industries (food, textiles, apparel, paper, printing, rubber and plastics, and primary metals), lower productivity combined with higher input prices (for all three types of inputs) to reduce competitiveness. Low input prices in 6 of the remaining industries were not strong enough to offset the effects of lower productivity and make these industries more competitive. No industry was less competitive but more productive than its U.S. counterpart (quadrant II).

An examination of quadrant III reveals that 10 Canadian industries were more competitive and more productive than the corresponding U.S. industries. Seven of these — coal mining; construction; lumber and wood; petroleum refining;

FIGURE 2

RELATIVE OUTPUT PRICES AGAINST RELATIVE TFP LEVELS, 1995
(U.S. = 1.00)



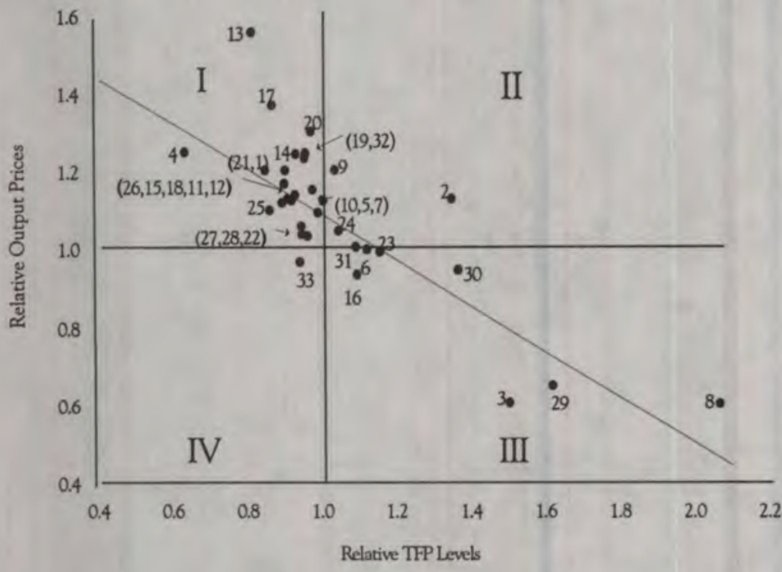
Note: The numbers in this figure refer to the industries listed in Table 2.

electric utilities; finance, insurance, and real estate (FIRE); and trade — were identified as having relatively lower input prices than their U.S. counterparts. The remaining 3 industries — tobacco, gas utilities, and motor vehicles — had higher input prices than their U.S. competitors, but the difference was not large enough to make them less competitive than the corresponding U.S. industries.

Finally, quadrant IV shows the industries where Canada was more competitive but less productive than the United States — chemicals; leather; industrial machinery; electrical machinery; miscellaneous manufacturing; communications; transportation and warehousing; and other services. Canada's competitive position in those cases stemmed from lower input prices rather than higher TFP levels. Thus, it appears that the main factor behind variations in international competitiveness across industries is the gap in relative TFP levels.

FIGURE 3

RELATIVE OUTPUT PRICES AGAINST RELATIVE TFP LEVELS, 1988 (U.S. = 1.00)



Note: The numbers in this figure refer to the industries listed in Table 2.

However, movements in international competitiveness over time are strongly influenced by variations in the exchange rate through relative input prices. For the purpose of illustration, we compare international competitiveness between 1988 and 1995. We plot relative output prices against relative TFP levels for 1988, as shown in Figure 3, to facilitate the discussion. In 1988, only 8 Canadian industries were more competitive than their U.S. counterparts, compared to 18 industries in 1995. This change is explained by the fact that the Canadian dollar depreciated by more than 10 percent during the intervening period. If the exchange rate in 1995 had remained at its 1988 level, only 9 Canadian industries would have been more competitive than their U.S. counterparts that year. In addition, several Canadian industries — lumber and wood, chemicals, leather, industrial machinery, motor vehicles, miscellaneous manufacturing, transportation and warehousing, and communications — would have lost ground and become less competitive than their U.S. counterparts by 1995.

CANADA-U.S. DIFFERENCES IN PRODUCTIVITY AND INTERNATIONAL COMPETITIVENESS IN THE PRIVATE BUSINESS SECTOR

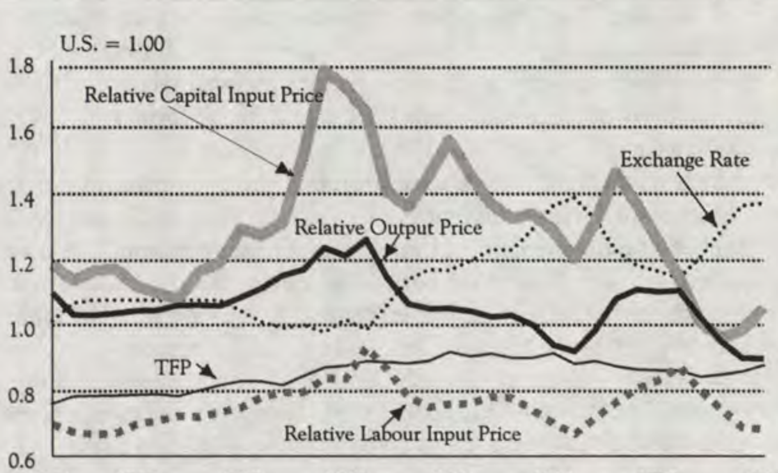
IN THIS SECTION, we examine the relative performance of the Canadian and U.S. private business sectors with respect to TFP levels and competitiveness over the 1961-95 period.[11] We plot relative TFP levels, relative output and input prices, as well as the exchange rate in Figure 4.

The results show that Canada's TFP levels were catching up to U.S. levels, rising from 76 percent of the U.S. level in 1961 to almost 92 percent in 1980. However, the gap between the two countries began to widen after 1985 and stood at 12 percent in 1995.

Meanwhile, Canada's relative competitive position worsened between 1963 and 1976. The deterioration would have been much worse without the improvements in relative TFP levels that occurred in the Canadian business sector over this period. Canada's competitive position then improved from 1976 to 1995, not as a result of TFP improvements but because of the Canadian dollar depreciation through its impact on relative input prices.

FIGURE 4

RELATIVE PRODUCTIVITY AND COMPETITIVENESS BETWEEN CANADA AND THE UNITED STATES IN THE PRIVATE BUSINESS SECTOR



Relative labour prices tend to be in line with relative output prices. Despite the volatility associated with the exchange rate, labour costs were consistently lower in Canada than in the United States over the 35-year period 1961-1995. In addition, the trend was fairly stable over that period. In contrast, relative capital input prices have been much more volatile. Since 1975, relative capital input prices have declined, in line with the depreciation of the Canadian dollar. In general, however, they have remained higher in Canada than in the United States, except in 1993 and 1994.

SUMMARY AND CONCLUSION

THIS STUDY ILLUSTRATES THAT IT IS CRITICAL TO USE PPPs rather than the market exchange rate to assess the relative productivity levels and international competitiveness of two countries. PPPs vary across industries and types of output and inputs. Based on a common framework and using comparable data sets, 23 of 33 Canadian industries had lower TFP levels compared to their U.S. counterparts in 1995. Relative TFP levels are an important element in determining international competitiveness. Our analysis indicates that Canadian industries with high relative productivity compared to their U.S. counterparts tend to be more competitive. Over time, however, movements in the exchange rate appear to be the most significant factor behind international competitiveness. From 1988 to 1995, the falling exchange rate helped 9 Canadian industries become more competitive than their U.S. counterparts.

Our analysis of the private business sector reinforces our findings at the industry level showing that movements in the exchange rate coincide with variations in relative output prices. Over the 1976-95 period, during which the competitiveness of Canada's private business sector improved relative to that of the U.S. private business sector, Canada's relative TFP performance did not improve, despite a slight rebound after 1993.

This study is a first step towards understanding the differences in productivity and international competitiveness between Canada and the United States. A number of refinements could prove fruitful. First, it would be useful to collect more data comparing prices between Canada and the United States in order to increase the reliability of PPP estimates. A second avenue would be to expand capital asset categories for Canada to match Jorgenson's categories for the United States or those of the U.S. Bureau of Labor Statistics. Future research may also benefit from an assessment of the comparability of the two countries' I-O tables, with a special focus on capital compensation data.

ENDNOTES

1 A description of the data is provided by Gu and Ho (chapter 2 of this volume).

2 See chapter 2 for data sources.

3 The I-O tables for both countries include make, use, final demand, and investment flow matrices.

4 The Canadian I-O tables are aggregated from 479 commodities and 170 industries; the U.S. tables are aggregated from 541 commodities and 541 industries.

5 These are 1993 PPPs, aggregated on the basis of data pertaining to more than 2,000 commodities obtained from Statistics Canada. Statistics Canada uses the data to estimate a bilateral GDP PPP between Canada and the United States.

6 Although these 249 commodities cover all commodities in the I-O tables, some of them may not be used as inputs. In that case, they are not entered into the calculation of input PPPs.

7 Hooper and Vrankovich (1995) adjust commodity PPPs for international trade in constructing output PPPs. Our analysis shows that incorporating this methodology does not significantly change the results since it is based on two restrictive assumptions: both export and import prices equal world prices; and world prices equal the average of prices in the two countries, weighted by their expenditures. Since we are unable to justify these two assumptions, we use output PPPs without international trade adjustments.

8 The output PPP for the private business sector is approximated by the bilateral value-added PPP for the total economy, as calculated by Statistics Canada.

9 An assessment of the implications of quality adjustments to capital and labour inputs for estimating relative TFP levels is found in the Appendix of this chapter.

10 Canada's capital intensity is based on an alternative set of capital stock estimates produced by the Investment and Capital Stock Division of Statistics Canada. These alternative capital stock estimates are based on the same declining-balance rates as those used in the United States. Capital intensity for Canada would be much lower if we used capital stock data from Statistics Canada's KLEMS database.

11 The aggregate price function gives the value-added price as a function of capital and labour input prices, so that the intermediate input price is excluded. Similar to Equation (8), the difference in the logarithms of the TFP levels between the Canadian and U.S. private business sectors can be expressed as the negative value of the difference between the logarithm of the value-added price and the weighted average of the difference between the logarithms of capital and labour input prices.

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APPENDIX

QUALITY OF CAPITAL AND LABOUR INPUTS AND RELATIVE TFP LEVELS

IN THIS APPENDIX, we first compare relative levels of capital and labour input quality in Canada and the United States and assess their implications for relative TFP levels. Following Dougherty (1992), we estimate relative capital input levels (PPP-adjusted) for Canada and the United States, with each country's asset type (M&E, structures, land, and inventories) weighted by the average compensation share in the two countries:

$$(A\text{-}1)\quad \ln\left[K_i(Can)/K_i(US)\right]=\sum_{k=1}^{4}1/2\left[v_{i,k}^{K}(Can)+v_{i,k}^{K}(US)\right]\cdot\ln\left[A_{i,k}(Can)/A_{i,k}(US)\right].$$

Here, $K_i(S)$ denotes capital input in industry i in country S, $v_{i,k}^{K}(S)$ is the capital compensation share of type k capital asset in total capital compensation in industry i in country S, and $A_{i,k}(S)$ is the net stock of type k capital asset in industry i in country S. We then use the following expression to estimate relative capital quality levels for Canada and the United States:

$$(A\text{-}2)\quad \ln\left[q_i^{k}(Can)/q_i^{k}(US)\right]=\ln\left[K_i(Can)/K_i(US)\right]-\ln\left[A_i(Can)/A_i(US)\right],$$

where $A_i(S)=\sum_{k=1}^{4}A_{i,k}(S)$ denotes the total capital stock in industry i in country S.

Likewise for capital input, relative labour input levels in Canada and the United States for industry i can be expressed as:

$$(A\text{-}3)\quad \ln\left[L_i(Can)/L_i(US)\right]=\sum_{j=1}^{112}1/2\left[v_{i,j}^{L}(Can)+v_{i,j}^{L}(US)\right]\cdot\ln\left[H_{i,j}(Can)/H_{i,j}(US)\right],$$

where $v_{i,j}^{L}(S)$ denotes the labour compensation shares of type j workers in industry i in country S, and $H_{i,j}(S)$ denotes the hours worked by workers of type j in industry i in country S. As with capital quality, relative labour quality levels are estimated by the following expression:

$$(A\text{-}4)\quad \ln\left[q_i^{L}(Can)/q_i^{L}(US)\right]=\ln\left[L_i(Can)/L_i(US)\right]-\ln\left[H_i(Can)/H_i(US)\right],$$

where $H_i(S)=\sum_{j=1}^{112} H_{i,j}(S)$

is the total number of hours worked by all types of workers in industry i in country S.

We then use the relative quality levels of capital and labour inputs to estimate relative raw TFP levels (commonly referred to as relative Solow residuals). The relationship between the relative raw TFP levels and our estimates of relative TFP levels is given below:

$$\text{(A-5)} \quad \overline{\varphi}_i^D = \overline{\upsilon}_i^D + \overline{\upsilon}_i^K \ln\left[\frac{q_i^K(Can)}{q_i^K(US)}\right] + \overline{\upsilon}_i^L \ln\left[\frac{q_i^L(Can)}{q_i^L(US)}\right],$$

where $\overline{\varphi}_i^D$ is the raw TFP, $\overline{\upsilon}_i^D$ is the TFP, and $\overline{\upsilon}_i^K$ and $\overline{\upsilon}_i^L$ are the average capital and labour compensation shares of the two countries in industry i, as discussed in the section entitled *Relative Productivity Levels*.

In Table A1, we report relative quality levels of capital and labour inputs and assess their implications for relative TFP levels. Generally speaking, there are some variations in the relative levels of capital quality across industries between Canada and the United States. On the other hand, labour quality in Canada is slightly lower than in the United States in virtually all industries. In most cases, the effect of capital quality is offset by labour quality, resulting in a slight difference between relative raw TFP levels and the estimated TFP levels that incorporate capital and labour input quality differences.

TABLE A1

RELATIVE CAPITAL AND LABOUR QUALITY LEVELS AND TFP LEVELS, 1995 (U.S. = 1.00)

INDUSTRY	CAPITAL QUALITY	LABOUR QUALITY	TFP	RAW TFP
1. Agriculture, Forestry and Fisheries	1.57	0.99	0.83	0.89
2. Metal Mining	0.92	0.96	0.90	0.86
3. Coal Mining	0.83	0.98	1.16	1.09
4. Crude Petroleum and Gas	0.91	0.92	0.71	0.66
5. Non-metallic Mining	0.93	1.00	0.96	0.94
6. Construction	1.02	0.97	1.18	1.16
7. Food	1.00	0.95	0.96	0.95
8. Tobacco	0.95	1.01	2.06	2.02
9. Textile	0.98	1.01	0.98	0.98
10. Apparel	1.00	0.97	0.99	0.98
11. Lumber and Wood	1.06	0.97	1.01	1.01
12. Furniture	0.99	0.98	0.96	0.96
13. Paper	1.11	1.00	0.83	0.84
14. Printing	0.93	0.96	0.88	0.86
15. Chemicals	1.01	0.96	0.93	0.92
16. Petroleum Refining	0.74	0.99	1.15	1.12
17. Rubber and Plastics	1.12	0.97	0.85	0.86
18. Leather	1.11	0.95	0.83	0.83
19. Stone, Clay and Glass	1.07	0.98	0.87	0.88
20. Primary Metals	1.20	0.97	0.96	0.97
21. Fabricated Metals	1.05	0.98	0.84	0.84
22. Industrial Machinery	1.04	0.96	0.88	0.87
23. Electrical Machinery	0.87	0.98	0.98	0.96
24. Motor Vehicles	1.67	0.94	1.07	1.09
25. Other Transportation Equip.	0.88	0.95	0.98	0.95
26. Miscellaneous Manufacturing	0.93	0.91	0.92	0.88
27. Transportation and Warehousing	0.81	0.97	0.87	0.84
28. Communications	1.00	0.97	0.99	0.98
29. Electric Utilities	0.98	0.98	1.24	1.22
30. Gas Utilities	0.97	0.96	1.15	1.13
31. Trade	0.83	0.95	1.02	0.97
32. Finance, Insurance and Real Estate	0.96	0.84	1.09	1.02
33. Other Services	1.00	0.94	0.93	0.90
Private Business Sector	1.02	0.97	0.88	0.86

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4

The Canada-U.S. Productivity Growth Paradox

SUMMARY

PRODUCTIVITY DATA ON THE BUSINESS SECTOR, which covers around 75 percent of the economy, provide important information on the evolution of living standards.

The data on multifactor productivity (MFP) growth and labour productivity growth produced by the official statistical agencies in Canada (Statistics Canada) and the United States (Bureau of Labor Statistics, or BLS) send mixed signals regarding the comparative evolution of living standards in the two countries. Since the early 1980s, Statistics Canada's MFP growth measures for the business sector indicate that the Canadian economy has outperformed the U.S. economy while labour productivity data produce a reverse picture. This is the so-called Canada-U.S. Productivity Paradox.

In this study, we investigate the productivity paradox with an analysis of Canadian and U.S. business sector productivity data since 1961. The main finding of our analysis is that business sector MFP growth estimates provided by Statistics Canada in March 1999 are neither consistent over time nor comparable to U.S. estimates.

The analysis identifies three significant problems with the methodology used by Statistics Canada for estimating MFP growth. First, Statistics Canada's labour force index is biased. The agency appears to significantly overestimate the contribution of the changes in the labour force composition in the 1960s compared with those in the 1980s and the 1990s. MFP growth in the 1960s is therefore underestimated compared with the 1980s and the 1990s.

Second, the concept of capital used by Statistics Canada appears too narrow for MFP growth measurement. By excluding land and inventories, which seem to grow at a substantially slower pace than the other components of the capital

stock, the Canadian statistical agency tends to overestimate the contribution of capital accumulation to output growth.

Third, Statistics Canada appears to systematically underestimate the transitory growth rate and the level of the capital stock in Canada. This underestimation of the capital stock stems from the methodology used by the Canadian statistical agency to account for depreciation. The bias engendered by the underestimation of the growth in the capital stock (third problem) more than offsets the bias generated by the narrow definition of the capital stock (second problem). As a result, Statistics Canada overestimates MFP growth by approximately a quarter of a percentage point annually.

Our conclusion is that Statistics Canada should thoroughly revise its methodology for estimating the capital stock and for measuring changes in labour force composition. The paper proposes methodological changes to address these problems.

INTRODUCTION

LABOUR PRODUCTIVITY AND MULTIFACTOR PRODUCTIVITY, two important and widely used indicators of the health of an economy, send very different messages about how well Canada has performed relative to the United States over the last few decades. Given the links between productivity growth and improvements in an economy's standard of living, this confusion also leads to uncertainty about the comparative evolution of living standards in the two countries.

The essence of the problem can be seen in Figures 1 and 2, which are based on the labour productivity and multifactor productivity (MFP) data for the business sector (Canada) and the private business sector (United States) produced by Statistics Canada and the U.S. Bureau of Labor Statistics (BLS). Since our interest is in long-run trends, cyclical fluctuations in the published data have been removed using a popular smoothing procedure known as the Hodrick-Prescott (HP) filter. The resulting patterns of productivity growth in Canada and the United States are very different. According to the MFP growth estimates presented in Figure 1, Canada does not have a productivity problem vis-à-vis the United States. Even if the average productivity *level* is lower in Canada than in the United States, this can only be temporary. Canada's faster productivity growth will lead this country's multifactor productivity to converge towards the U.S. level. The labour productivity measure portrayed in Figure 2 suggests, on the contrary, that convergence was a phenomenon of the 1960s and 1970s. Since 1980, Canada's average productivity growth (1.05 percent) has been well below that of the United States (1.24 percent), and the gap in productivity levels between the two countries has widened.

FIGURE 1

TREND IN MULTIFACTOR PRODUCTIVITY (MFP) GROWTH, CANADA AND THE UNITED STATES

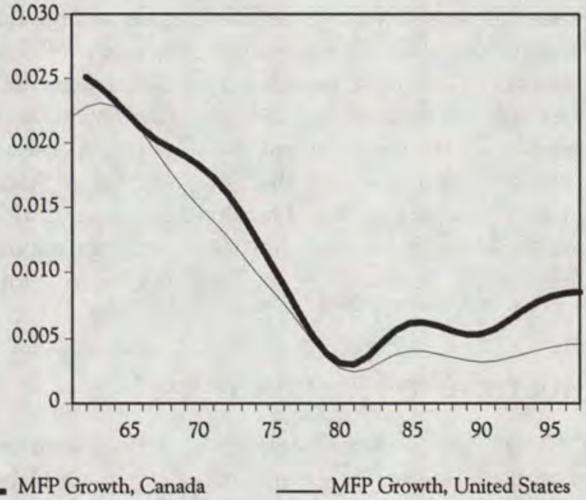
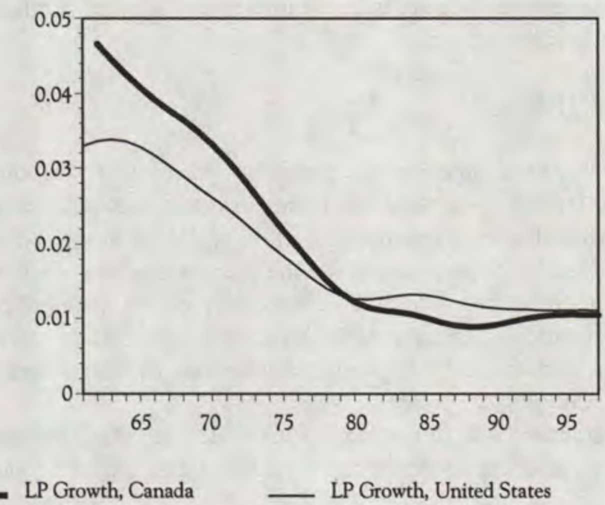


FIGURE 2

TREND IN LABOUR PRODUCTIVITY (LP) GROWTH, CANADA AND THE UNITED STATES



Do these very different pictures of Canada's performance reflect the influence of some economic factor(s) that are more effectively captured by one than the other productivity measure, or are they simply an artefact of productivity measurement? We argue that what we have called the productivity paradox is, indeed, a statistical rather than an economic phenomenon. There are differences in the procedures employed by Statistics Canada and the Bureau of Labor Statistics to measure multifactor productivity[1] and, as a result, comparisons of published estimates of MFP growth provide very misleading results. In this paper, we identify three specific methodological differences and show that each has serious consequences for the measurement of MFP. It is proposed that Statistics Canada apply the procedures used by the Bureau of Labor Statistics for MFP measurement, partly because this would facilitate comparison with U.S. results, but also because the U.S. methodology has some desirable features that should be incorporated in the measurement of Canada's multifactor productivity growth.

What Is Multifactor Productivity?

Multifactor productivity measures how much output an economy produces with the use of a given amount of capital and labour. Increases in MFP show to what extent we are succeeding in extracting greater value out of the economy's limited resources. MFP growth records improvements in the economy's productive potential resulting from increases in knowledge and the use of more efficient production processes.

In the neoclassical growth model, the factors underlying the growth of MFP went under the general title of technological progress. The role of technological progress can be seen in the standard neoclassical production function with constant returns to scale,

$$Y(t) = F\,[K(t), A(t)L(t)]$$

where output (Y) is a function (F) of the capital stock (K), labour (L), an efficiency parameter (A) and time (t). Here, technological progress is the growth rate, $g(t)$, of the efficiency parameter $A(t)$. In the basic model, where the labour force is assumed to be homogeneous, the increases in output per worker that are needed to raise living standards can only occur through growth in the capital/labour ratio or through technological progress. When the economy is in its long-term steady state, the required increases in output per worker must come from technological progress.[2]

Under standard accounting frameworks, MFP growth is measured residually by deducting the contribution made by capital and labour to output growth.

To develop an appropriate measure, changes in capital and labour must be properly measured and these factors must be assigned weights that reasonably correspond to their importance within the economy. Such an accounting exercise is far from straightforward. Statistics Canada and the Bureau of Labor Statistics have pursued very different approaches to some of the main underlying measurement issues, notably: the treatment of changes in labour force characteristics; the definition of capital stock; and the estimation of capital depreciation. Below, we look at each of these issues and show that the divergences between Canadian and U.S. methodologies have very substantial measurement implications.

ACCOUNTING FOR CHANGES IN LABOUR FORCE CHARACTERISTICS

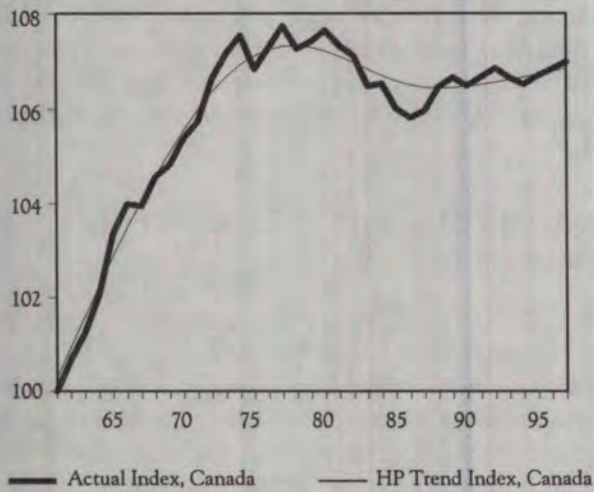
IN CALCULATING THE CONTRIBUTION of labour to output growth, both Statistics Canada and the Bureau of Labor Statistics attempt to take account of changes in the characteristics of the labour force, but they go about this in different ways. Statistics Canada attempts to capture changes in the quality of the labour force through an index (Fisher Index) that weights workers by their industry wages. This is designed to take account of changes in the quality of the labour force from changes in labour composition across industries. The index used by the Bureau of Labor Statistics to adjust for changes in labour quality takes explicit account of changes in the male/female mix of workers along with increases in worker experience; it also attempts to incorporate the contribution of increased schooling to improving labour quality.[3]

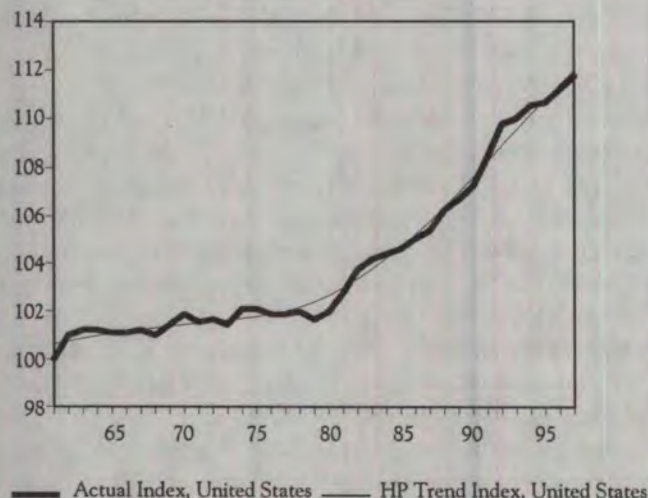
In Figures 3A and 3B, we show the original data and the trend growth rate in labour force compositional indices that result from applying these different approaches.[4] The U.S. index is taken from the BLS data bank, while the Canadian index has been computed from published data. HP-adjusted trends are depicted in Figure 3A and the trend growth rates in Figure 3B. For the United States, data are available from 1949 and are portrayed in Figure 3B from that date to present a historical perspective.

With the exception of the 1975-80 period, the U.S. index tends to grow over time which is consistent with a priori expectations that the quality of the U.S. labour force has been steadily increasing due to higher levels of educational attainment. The decline in the U.S. trend growth rate between 1965 and 1980 reflects the decline in average worker experience that occurred with the massive entry of members of the baby-boom cohort in the labour market. Similarly, the subsequent rise in the trend growth rate is largely attributable to the gradual ageing of baby-boom workers and the consequent increase in the average experience level of the U.S. labour force.

FIGURE 3A

ACTUAL AND ADJUSTED* TREND COMPOSITION OF THE LABOUR FORCE INDEX, CANADA AND THE UNITED STATES

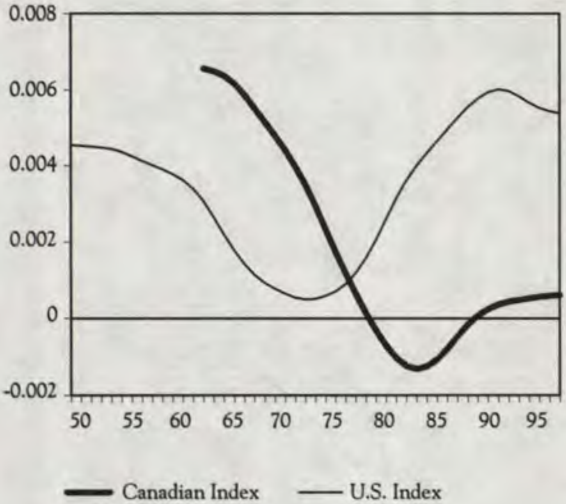




Note: * Adjusted with a smoothing procedure known as the Hodrick-Prescott (HP) filter.

FIGURE 3B

TREND GROWTH RATE IN THE COMPOSITION OF THE LABOUR FORCE INDEX, CANADA AND THE UNITED STATES

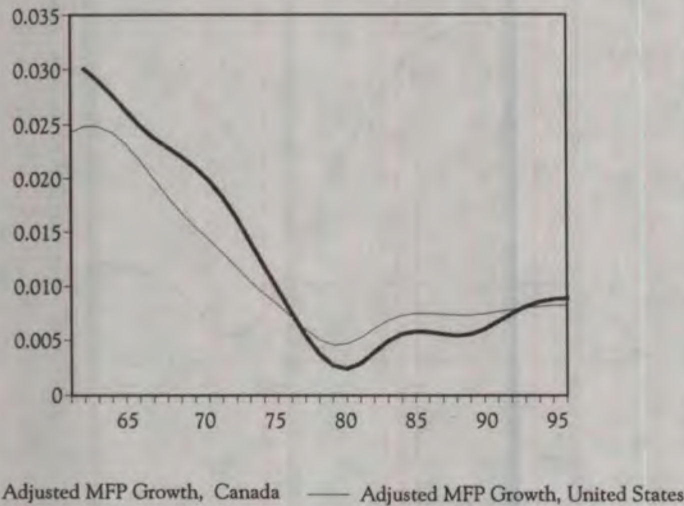


The pattern of the Canadian index is more difficult to understand. The negative growth rates between the mid-1970s and the early 1990s point to a decline in the productive quality of the Canadian labour force. This is puzzling since, over this period, Canadian workers, like their U.S. counterparts were, on average, becoming better educated and more experienced. It is also not clear why the Canadian compositional index was growing so much faster than the U.S. index during the 1960s. Figures 3A and 3B suggest that, over the 1960s, the positive impact of shifts in industrial activity on labour quality were much greater in Canada than in the United States. It further suggests that the net labour quality gains to Canadian workers from this source significantly exceeded the qualitative gains from the educational improvements that U.S. workers experienced and that are explicitly incorporated in the U.S. index. There is clearly something wrong in the story that unfolds from a comparison of the Statistics Canada and BLS labour force compositional indices. The application of different methodologies has resulted in labour force adjustments to Canada and U.S. data that are inconsistent with each other.

The statistical agencies' different approaches to adjusting for labour quality have important implications for MFP growth calculations. If our suspicion is correct — that improvements in the quality of the Canadian labour force have been overestimated for the 1960s, as compared to the last 20 years —

FIGURE 4

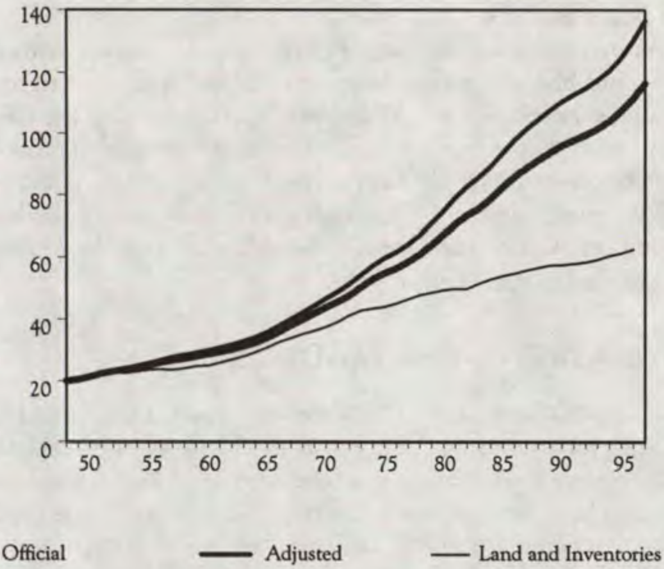
ADJUSTED TREND MFP GROWTH ESTIMATES, CANADA AND THE UNITED STATES
(EXCLUDING CHANGES IN LABOUR FORCE COMPOSITION)



then MFP growth in Canada has been underestimated in the 1960s relative to growth over recent decades. To provide a sense of the possible bias from inappropriate adjustments, we have calculated MFP growth measures for Canada and the United States excluding labour force compositional changes. The results, smoothed to capture trend growth rates, are shown in Figure 4. The adjusted trends are very different from those of Figure 1. Most significantly, with this illustrative adjustment we have eliminated the productivity paradox. MFP growth is higher in Canada than in the United States only in the first part of the period covered in Figure 4. From the end of the 1970s to the early 1990s, the United States' performance is superior, which is consistent with what is indicated by labour productivity data (Figure 2).

FIGURE 5

OFFICIAL AND ADJUSTED MEASURES OF THE CAPITAL STOCK IN THE UNITED STATES



THE DEFINITION OF CAPITAL STOCK

THE ECONOMY'S CAPITAL STOCK poses some of the most complex conceptual and measurement issues. Statistics Canada and the Bureau of Labor Statistics have adopted different approaches to a number of central aspects, including the basic question of how to define the capital stock. The Bureau of Labor Statistics applies a broad definition, in which the capital stock includes five components: equipment, structures, rental residential capital, inventories, and land. Statistics Canada uses a narrower definition which includes only three components: equipment, structures, and rental residential capital.

The significance of these differences in approach are revealed by adjusting U.S. capital stock data to the narrower Statistics Canada definition. From Figure 5, it can be seen that the adjusted measure of U.S. capital stock excluding land and inventories tends to grow at a faster rate than the official BLS measure.[5] This result is not surprising since, by excluding land and inventories, we are removing the slowest growing components of the U.S. capital stock. Published U.S. statistics show that the share of equipment in the total capital stock has risen continuously since 1948, the first year for which data are available.

The difference between the official BLS measure and the adjusted measure corresponding to Statistics Canada's capital stock definition is substantial. Over the 1961-97 period, the adjusted measure grew at an average annual rate of 4.1 percent, while the official U.S. measure including land and inventories increased at a rate of 3.8 percent. The cumulative growth rate differential over the entire period is 15.3 percent.

By comparison to the U.S. approach, Statistics Canada's methodology imparts an upward bias to the measurement of capital stock growth and a downward bias to the calculation of MFP growth. We estimate that the effect of using a narrower rather than a broader concept of capital stock is to reduce the MFP growth rate by one-tenth of 1 percentage point per year over the 1961-97 period. While this is a small number, MFP annual growth rates are also modest, typically around 1 percent.[6] Consequently, the underestimation amounts to approximately 10 percent of total annual MFP growth.

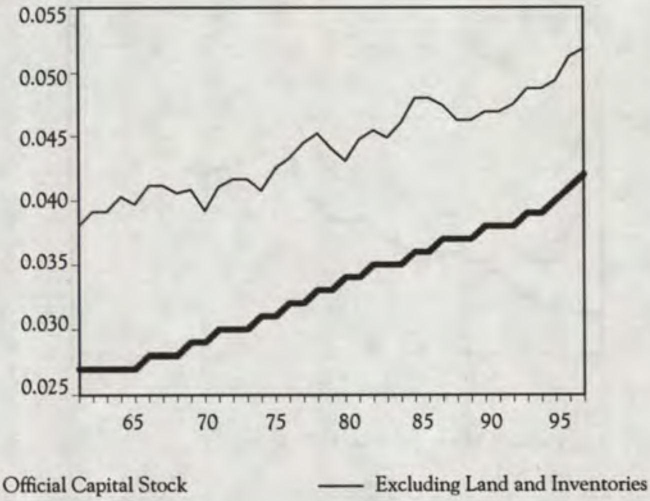
The Estimation of Capital Depreciation

Another important difference between the Canadian and U.S. methodologies for measuring MFP lies in their treatment of capital depreciation. It is necessary to take account of the deterioration of capital and the fact that, for example, a piece of machinery does not have the same productive capacity today as when it was purchased twenty years ago, but it is very difficult to estimate the rate at which capital is deteriorating. Experts might reasonably adopt different approaches to this problem.

In measuring the growth of capital stock for MFP measurement in the U.S. business sector, the Bureau of Labor Statistics follows closely a methodology developed by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce.[7] The Bureau of Labor Statistics and Statistics Canada model depreciation in different ways. While Statistics Canada uses a "geometric truncated" model for measuring capital inputs in MFP accounting, the BLS applies a hyperbolic function which is very close to the "geometric infinite" function adopted by the BEA. The key difference between these two modelling (BLS-BEA versus Statistics Canada) approaches is in their treatment of asset retirement. In Statistics Canada's methodology, a retirement pattern (the truncation), independent of the depreciation rate, specifies the age at which an asset is discarded or retired. In the BLS-BEA methodology, the pattern of asset retirement is determined by the infinite (geometric or hyperbolic) depreciation model. The geometric truncated model used by Statistics Canada tends to generate a much higher aggregate depreciation rate than the geometric infinite model applied by the BLS.

FIGURE 6

AGGREGATE EFFECTIVE DEPRECIATION RATE, U.S. BUSINESS SECTOR

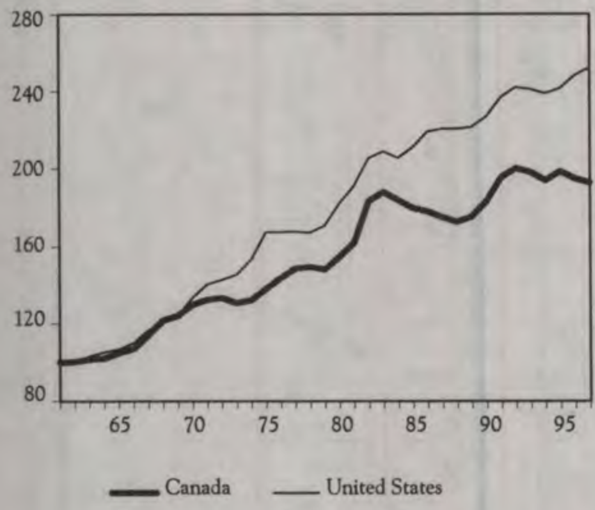


In a recent Statistics Canada working paper (Koumanakos et al. 1999), it is shown that, if the agency were to switch to the BEA methodology for geometric depreciation, this would have dramatic consequences on the measurement of Canada's capital stock. Using the BEA methodology for depreciation, Canada's capital stock would be two and one-half times larger for 1998 than with current Statistics Canada methodology. Furthermore, the growth rate of the capital stock would be much higher; by applying BEA depreciation procedures, the growth of Canada's capital stock since 1980 increases by about 1 percent per year.

In the United States, the BLS publishes implicit aggregate depreciation rates for the business sector. We have computed the implicit aggregate depreciation rate for a capital concept corresponding to that used in Canada by excluding land and inventories. Time series for both the official measure and our adjusted measure of the U.S. capital stock are shown in Figure 6. Both depreciation rates increased over 1961 to 1997, primarily because equipment, the class of capital goods with the highest depreciation rate, became a steadily increasing important component of the aggregate capital stock.

FIGURE 7

EVOLUTION OF THE CAPITAL/LABOUR RATIO, CANADA AND UNITED STATES



Note: 1961 was arbitrarily set at 100 for both countries; exluding land and inventories from private business sector capital stock data in the United States.

For the capital concept that excludes land and inventories, the aggregate implicit depreciation rate in the United States averages 4.4 percent between 1961 and 1997. This compares with the depreciation rate of 10 percent used to estimate the growth of Canada's business sector capital stock for MFP measurements. This is a big difference, to say the least. Such a difference in aggregate depreciation rates might be expected to have a large impact on the growth of capital stock and important implications for the measurement of MFP growth.

The consequences of Canada's use of a higher depreciation rate can be partly seen in how this approach affects the capital/labour ratio. In Figure 7, we have plotted the capital/labour series used by Statistics Canada for MFP calculations against the capital/labour ratio for the adjusted U.S. capital stock based on Statistics Canada's definition (i.e. excluding land and inventories). Labour is measured in hours and both series have been scaled at 100 in 1961. Figure 7 depicts the much weaker growth of Canada's capital/labour ratio. Between 1961 and 1997, the Canadian index increased only by 92.8 percentage points, well below the 152.8 percent increase of the U.S. index.

Aside from the disparity in the capital/labour ratio growth, Figure 7 highlights another interesting result of the comparatively high depreciation rates used by Statistics Canada: between 1984 and 1997, the growth of the capital/labour ratio in Canada virtually came to a halt. This is curious. It cannot be reconciled with the picture of Canada's performance portrayed by broad economic indicators. Moreover, it appears inconsistent with the 1.1 percent average annual labour productivity growth Canada has experienced between 1984 and 1997. It is difficult to find a model that will accommodate a stable capital/labour ratio with 14 years of steadily increasing labour productivity.

IMPACT OF DIFFERENT TREATMENTS OF CAPITAL ON MFP MEASUREMENT

THE TWO DIFFERENCES WE HAVE IDENTIFIED in the Canadian and U.S. agencies' treatment of capital have opposite effects on the measurement of MFP growth. While Statistics Canada's higher depreciation rate and its resulting estimates of relatively slow growth in the capital/labour ratio contributes to higher estimates of MFP growth, its use of a relatively narrow definition of capital stock creates an upward bias in its measurement of capital stock growth and a downward bias in its calculation of MFP growth. What is the net effect of these two statistical discrepancies on the measurement of MFP growth in Canada vis-à-vis the United States?

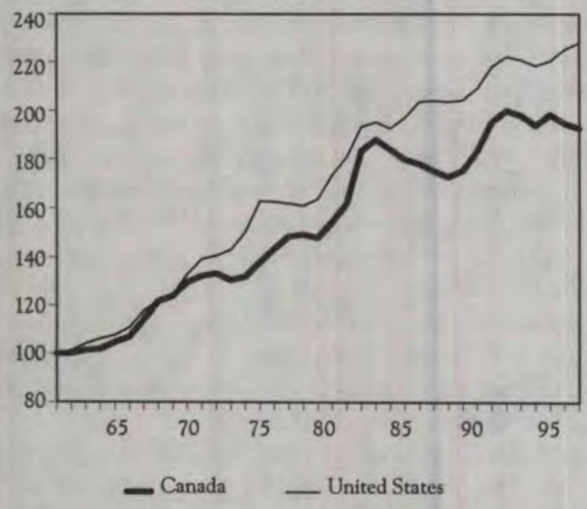
Figure 8 makes a start at addressing this question. Here we have plotted the evolution of the capital/labour ratio in the two countries, using the narrow definition of capital for Canada and the broad definition, which includes land and inventories, for the United States. Although the slower growing components of capital (land and inventories) have been excluded in the Canadian approach, the capital/labour ratio in Canada is growing at a much slower pace than in the United States. The downward bias in Statistics Canada's estimation of capital stock growth arising from the application of a comparatively high depreciation rate appears to more than offset the upward bias from its use of a relatively narrow concept of capital. Between 1961 and 1997, the cumulative growth rate of the U.S. capital/labour ratio exceeded the growth rate of Canada's capital labour ratio by 32.2 percent.

Since, on balance, the contribution of capital to economic growth is being underestimated in Canada by comparison to the United States, the growth of Canada's multifactor productivity is being overestimated relative to the United States. We can roughly estimate the magnitude of this bias. For the 1961-97 period, the cumulative increase in Canada's narrow capital stock was 30 percent smaller than the increase in the U.S. broad capital stock — our estimate here is consistent with that of Koumanakos et al. (1999). With the returns to business capital representing approximately one-third of national income, the cumulative overestimation of Canada's MFP growth between 1961 and 1997 works out to about 10 percentage points. This suggests that MFP growth has been overestimated, relative to the United States, by a little more than 0.25 percentage point per year. Since MFP growth has been in the range of 0.5 to 1 percentage point in recent years, what we have here is a very large measurement bias.

Another consequence of using an excessive depreciation rate is that the *level* of the capital stock is underestimated. Doubling the depreciation rate, for example, will lead, over the long-run, to a capital stock that is roughly twice smaller. If Canada's capital stock is underestimated, the growth rate of the capital stock is likely more variable. This, in turn, should translate into an increased variability in MFP growth. Indeed, we have found that, over the 1961-97 period, the standard deviation for the growth rate of the Canadian capital stock is 1.89 percent, well above the 1.10 percent we calculated for the adjusted U.S. capital stock excluding land and inventories. The Canadian series is 54 percent (logarithmic percentage) more variable than the U.S. series due primarily to differences in statistical procedures.

FIGURE 8

EVOLUTION OF THE CAPITAL/LABOUR RATIO, CANADA AND THE UNITED STATES

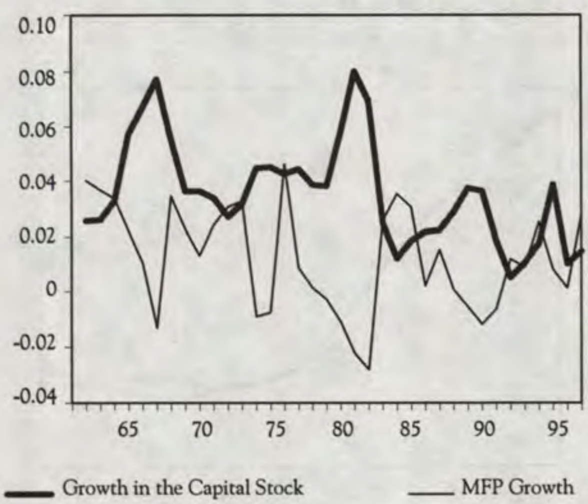


Note: 1961 was arbitrarily set at 100 for both countries; including land and inventories for the United States, excluding land and inventories for Canada.

Finally, and as way of highlighting our concerns about the Canadian capital stock data, it is useful to look at what happens when we apply an interesting test of proper capital stock measurement.[8] On theoretical grounds (based on both neoclassical and endogenous growth models), there should be a positive correlation between MFP growth and the growth of the capital stock. The positive relationship between changes in technological progress and the growth in the capital stock is likely to follow a dynamic pattern with lags. So, a priori, one should observe a positive or a null contemporaneous correlation between MFP growth and the growth of the capital stock. For the United States, the contemporaneous correlation between MFP growth and the growth in the capital stock is -0.017 for the 1948-97 period and -0.059 for the 1961-97 period. These coefficients are so small that they cannot be interpreted as indications of mismeasurement. In Canada, however, the correlation between MFP growth and the growth of the capital stock is -0.450 for the 1961-97 period and a striking -0.7444 for the 1980-97 period. These significant negative correlations, which are illustrated in Figure 9, raise serious questions about the capital stock data used for MFP measurement in Canada.

FIGURE 9

NEGATIVE CORRELATION BETWEEN MFP GROWTH AND THE GROWTH OF THE CAPITAL STOCK IN CANADA



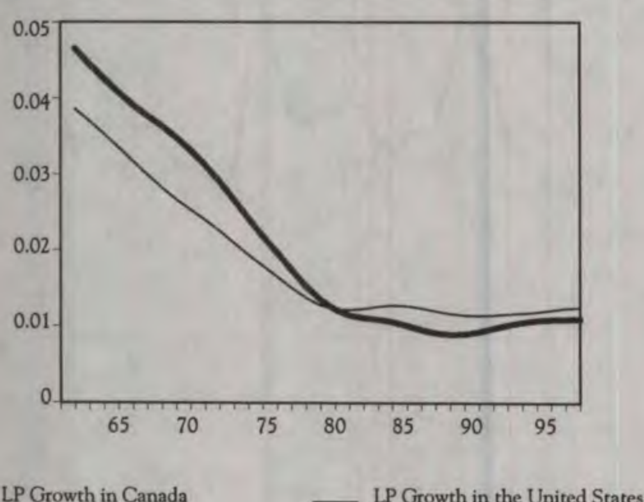
DOES CANADA HAVE A PRODUCTIVITY PROBLEM?

SINCE SERIOUS METHODOLOGICAL DIFFERENCES make it inappropriate to compare the MFP growth calculations of Statistics Canada and the Bureau of Labor Statistics, what can we say about Canada's productivity performance? Does Canada indeed have a productivity problem in relation to the United States?

To shed light on this issue, Figure 10 examines labour productivity growth in the Canadian and U.S. business sectors. The U.S. business sector is more comparable to its Canadian counterpart than is the U.S. private business sector, for which the Bureau of Labor Statistics produces MFP estimates. Again, the actual productivity data were smoothed using the HP filter, and logarithmic changes were computed to establish trend growth rates. The results are similar to those presented in Figure 2, which depicts labour productivity growth for the business sector in Canada and the private business sector in the United States. Both charts show Canada performed comparatively well up to 1980, after which Canada's productivity growth began to trail behind that of the United States. Figure 10, however, reveals two additional points. First, it shows that the trend labour productivity growth in the U.S. business sector paralleled that of its Canadian counterpart in the early 1960s, contrary to what is depicted in Figure 2. Second, Figure 10 indicates that the gap, between the trend growth rates

FIGURE 10

TREND IN LABOUR PRODUCTIVITY (LP) GROWTH IN THE BUSINESS SECTOR, CANADA AND THE UNITED STATES



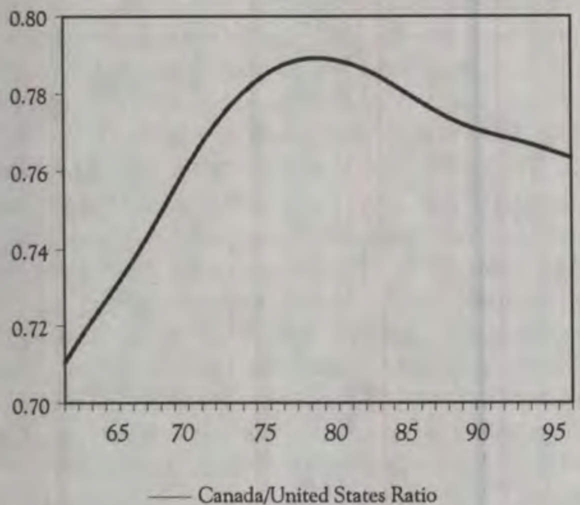
of the two countries since 1993 is somewhat larger than previously described. Over the 1980-98 period, the relationship between the two countries was relatively stable, with labour productivity growth in the United States averaging 1.28 percent per year compared to 1.03 percent for Canada. Thus, over the past 18 years, private sector labour productivity growth in the United States has exceeded that of Canada, on average, by 0.25 percentage point per year.

To get a complete picture of Canada's performance, the analysis of labour *productivity growth rates* needs to be supplemented by an examination of relative *productivity levels* in Canada and the United States. In the absence of official measures of labour productivity levels, we have developed rough estimates using 1961 calculations of GDP per capita in Canada and the United States, adjusted to take account of differences in purchasing power. These 1961 purchasing power parity (PPP) estimates of GDP per capita are taken from the Summers-Heston database, a source which is widely used in empirical studies of growth across countries. We assume that the Canada/U.S. ratio we have derived from this database (0.7104) provides a reasonable estimate of the relationship that existed between Canadian and U.S. labour productivity in 1961. Thereafter, we calculate the change in relative productivity levels using the trend growth rates in Canadian and U.S. labour productivity depicted in Figure 10. The result, which is illustrated in Figure 11, is a rough estimate of productivity levels based on trend labour productivity growth rates, with an initial value that is anchored to the Summers-Heston estimates of PPP-adjusted GDP per capita in Canada and the United States.

Although Canadian labour productivity was converging towards the U.S. level in the early part of the period examined, by 1980 — after 19 years of convergence — less than a quarter of the gap had been closed. Moreover, convergence came to a halt in 1980 and, since then, the gap between Canadian and U.S. productivity levels has gradually widened. This analysis suggests that, based on its performance in relation to its major foreign competitor, Canada does have a productivity problem. There is room for debate about the statistical significance of the mean difference in growth rates after 1980, since even the measurement of labour productivity is subject to some degree of uncertainty. For example, Gordon (1999) argues that recent improvements in U.S. labour productivity growth are largely attributable to a change in the methodology used for incorporating the effects of declining computer hardware prices. Allowing for a margin of statistical error then, at best, as Fortin (1999) points out, Canada appears to have a 'level problem', since Canadian productivity levels are below those of the United States and the gap is not closing. At worst, the productivity level in the Canadian business sector is lower than in the United States and the gap is increasing.

FIGURE 11

ESTIMATED TREND IN LABOUR PRODUCTIVITY LEVELS



THE NEED FOR NEW ESTIMATES OF CANADA'S MFP GROWTH

WHILE THERE IS SCOPE FOR DISCUSSION and debate about the finer statistical points of MFP estimation, we can see considerable value in drawing upon U.S. methodology to construct a revised set of MFP growth estimates for Canada. MFP growth statistics that can be compared with estimates for the United States could provide us with additional insights into Canada's economic performance. Moreover, by introducing a revised methodology based on the current U.S. approach to MFP estimation, Statistics Canada would address a number of major questions raised by its procedures.

A new approach modelled on U.S. methodology could serve a number of purposes. First, it should eliminate the anomalies in the statistical portrait of how Canada's labour force has evolved over time. As we noted, there is something troubling in the current statistical picture which indicates that the productive capacity of Canada's labour force improved rapidly over the 1960s but declined through the 1980s. Further questions are raised when the pattern of labour force evolution in Canada is compared with that of the United States based on the data published by the Bureau of Labor Statistics.

Second, it would result in the adoption of a broader definition of the capital stock — one which is theoretically more appropriate given the procedure Statistics Canada is using to estimate the contribution of capital changes to MFP growth. Since the contribution of capital calculated by subtracting labour income from national income includes the contribution of land and inventories, these latter components should also be included in the measurement of the capital stock. The alternative would be to continue to exclude land and inventories, but to develop an alternative weighting system corresponding to the share of this narrower concept of capital in national income.

Third, it would address concerns relating to Statistics Canada's use of the geometric truncated model for capital depreciation. This approach results in an excessively high depreciation rate, which leads to an underestimation of the level of the capital stock. The Canadian capital stock is also highly variable. Most year-to-year movements in MFP may, indeed, mainly reflect problems in measuring Canada's capital stock.

Labour productivity data for the business sector indicate that Canada's performance has lagged behind that of the United States since the 1980s. The substantial gap in labour productivity levels that appears to have long been a feature of Canada's economic relationship with the United States, was only very partially closed as a result of Canada's relative strong performance over the 1961-80 period. Since 1980, no further progress has been made; if anything, the gap has widened somewhat. However, part of the story is missing. It would be extremely useful to have the additional perspective on Canada's performance made possible by statistically compatible Canadian and U.S. estimates of MFP growth. Statistics Canada would render an important service by making the needed changes to its methodology for estimating MFP growth.

ENDNOTES

1 This point was already acknowledged in a September 1999 article published by Statistics Canada (Wells et al., 1999).

2 Rymes (1971) has emphasized the need to correct the estimation of MFP growth to account for the effect of technological progress on the growth in the capital/labour ratio. He has advocated the use of an adjusted MFP growth concept called "Harrod-neutral multifactor productivity growth."

3 For methodological details on the BLS measure of labour force composition changes, refer to Bureau of Labor Statistics (1999a).

4 The labour force compositional index (C) is calculated by dividing the Fisher labour quality adjustment index (F) by a Laspeyres index (L) which measures changes over time in total hours worked.

5 The adjusted measure was computed by the author.

6 Diewert and Lawrence (1999), from a completely different methodology and using Canadian data only, arrive at exactly the same number. They estimate that the exclusion of land and inventories as input decreases multifactor productivity growth in Canada by 0.1 percent per year.
7 For a detailed description of the BLS methodology for measuring capital input for MFP growth, refer to BLS (1999b).
8 Credits for the following argument should be given to Pierre Duguay.

ACKNOWLEDGEMENTS

CREDITS SHOULD BE GIVEN to Jean-Pierre Maynard from the Micro-Economic Analysis Division, Statistics Canada, for his precious contribution in providing data banks on productivity (from both Statistics Canada and the Bureau of Labor Statistics) used in this paper. The author benefited from discussions with Pierre Duguay and Tom K. Rymes, and from comments provided by Jeffrey Bernstein, Erwin Diewert and Ronald Hirshhorn on an earlier version of the paper. However, the author is solely responsible for the views expressed in this paper and for any remaining errors and omissions.

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5

The Role of Industrial Structure in Canada's Productivity Performance

INTRODUCTION

THERE HAS LONG BEEN RECOGNITION that the ongoing reallocation of resources among firms, industries, sectors and regions has a profound influence on Canada's productivity performance. Through the 1950s and 1960s, the shift of resources from agriculture to higher productivity sectors, notably manufacturing, made an important contribution to Canada's aggregate productivity growth.[1] More recently, there have been concerns that the movement of capital and labour from goods- to services-producing sectors of the economy has been a factor in the deterioration of Canada's productivity performance.[2] Research aimed at determining to what extent the latter may simply be a measurement phenomenon, reflecting our inability to accurately record the growth in service sector output, has become an important activity in its own right.[3]

This study investigates the role of industrial structure as one of a number of possible determinants of Canada's lagging manufacturing productivity performance compared to the United States. By focusing on manufacturing, we avoid the problems involved in measuring service sector output and productivity growth. Moreover, our emphasis is on labour productivity where, in contrast to total factor productivity (TFP), published Canadian and U.S. data are reasonably comparable.[4] While there have been related studies based on TFP data, the significant contribution of industrial structure to differences between Canadian and U.S. productivity performance — and thereby to differences in the rate of improvement of living standards in the two countries — is well demonstrated by labour productivity measures.

The next section, entitled *Manufacturing Sector Performance*, provides an overview of Canadian manufacturing and of recent changes in productivity and competitiveness. Then, the role of industrial structure in explaining the labour productivity gap between the manufacturing sectors of the two countries is

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examined in the section entitled *Industrial Structure and the Productivity Gap*. The reasons for observed differences in the pattern of industrial development within the Canadian and U.S. manufacturing sectors are analyzed in the section entitled *Understanding Different Patterns of Industrial Development*. The following section, entitled *Factors Influencing the Competitiveness of Canadian Firms*, explores the link between the industrial structure and other causes of Canada's lagging productivity performance, and identifies some of the factors underpinning both the differences in productivity between similar Canadian and U.S. industries and the differences in the industrial composition of the two countries' manufacturing sectors. Finally, the last section summarizes the key findings of the study.

Manufacturing Sector Performance

Despite the long-term trend from goods to services production, manufacturing continues to be an important component of the Canadian economy. In 1999, manufacturing accounted for 18 percent of gross domestic product (GDP) and 14 percent of total employment. Over the past decade, the manufacturing sector's share of Canadian employment has declined, but its share of output has increased marginally (Figure 1). Moreover, the sector continues to be a source of relatively high paying jobs, with worker compensation at about 25 percent above the Canadian average.

Manufacturers are responsible for about two-thirds of total R&D spending in Canada (Figure 2). This sector also has played an important role in creating the trade and investment links through which Canada accesses foreign technology and know-how that is critical to long-term growth in per capita incomes. Manufacturing accounts for the bulk of Canada's merchandise trade and for about half of Canada's inward stock of foreign direct investment (FDI).

The productivity performance of the manufacturing sector is of special significance because of Canada's position as a small economy with a heavy dependence on foreign trade and investment. The importance of exports and FDI, measured by their size relative to gross output, is shown in Figure 3. In 1996, both the export intensity and FDI intensity of manufacturing were several times greater than in the United States. Canadian manufacturing firms are necessarily engaged in vigorous competition to increase exports and to attract foreign investment. If the sector's productivity performance is weak, pressure will mount to sustain competitiveness through reductions in real wages and/or declines in the exchange rate, both of which will lower Canadian living standards.

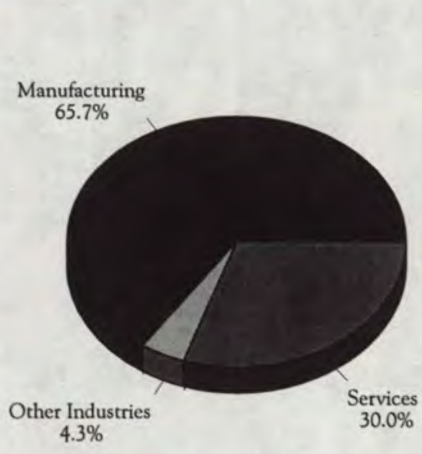
FIGURE 1

SHARE OF MANUFACTURING IN TOTAL GDP AND EMPLOYMENT IN CANADA (PERCENT)

Source: Statistics Canada.

FIGURE 2

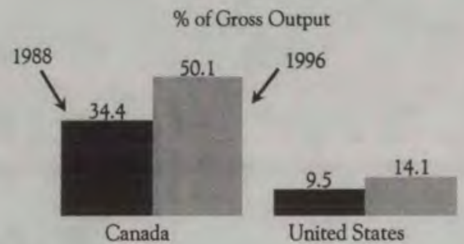
SHARE OF INTRAMURAL R&D SPENDING, 1998* (PERCENT)



Note: * Preliminary estimates.
Source: Statistics Canada, *Industrial Research and Development, 1995-1999.*

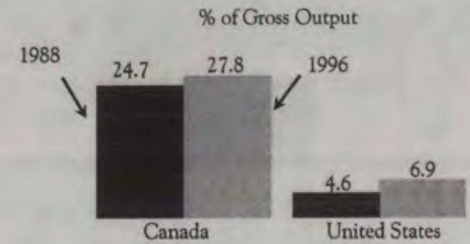
FIGURE 3

EXPORT INTENSITY*, MANUFACTURING



Note: * Exports as a percentage of total gross output.
Source: OECD, 1998 STAN Database.

FDI INTENSITY*, MANUFACTURING



Note: * FDI as a percentage of total gross output.
Source: Statistics Canada, Bureau of Economic Analysis, and the OECD, 1998 STAN Database.

As compared to the United States, this country's main trade competitor, Canada's labour productivity performance has indeed been weak. Between 1980 and 1996, labour productivity in manufacturing grew only about half as fast in Canada as in the United States (Figure 4). Although there has been some improvement in comparative performance since 1989, productivity growth in Canada continues to trail well behind that in the United States.

The sector-wide results reflect the superior productivity performance of U.S. firms in most manufacturing industries. Over 1980-96, productivity growth was faster in the United States than in Canada in 14 out of 19 manufacturing industries (Figure 5). In the top two performing U.S. industries — electronic and electrical equipment, and industrial machinery and equipment — productivity grew over twice as fast in the United States than in Canada.

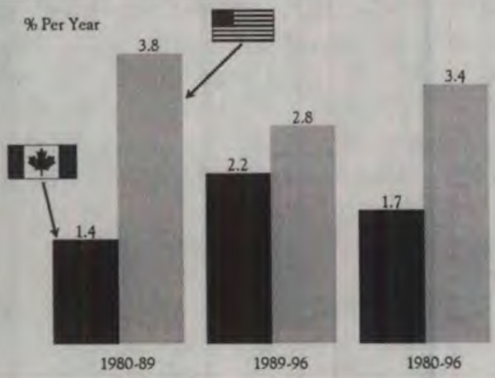
As a result of Canada's comparatively poor productivity performance, the gap in absolute productivity levels between Canadian and U.S. manufacturing has widened. Between 1993 and 1999, the discrepancy in manufacturing productivity expanded from 20 percent to 31 percent, an increase of more than one half. In contrast to and in spite of the widening productivity gap in the manufacturing sector, the aggregate labour productivity gap between Canada and the United States has remained relatively constant, at about 15-20 percent, since 1980 (Figure 6).

The productivity gap in manufacturing is broadly based. In 1996, only 4 of 19 Canadian industries had a higher level of labour productivity than their U.S. counterparts. Aside from these 4 industries — primary metals, paper and allied products, lumber and wood, and transportation equipment — GDP per worker in Canada tends to be much lower than in the United States (Figure 7).

Canada's poor manufacturing productivity performance has also reduced this country's international competitiveness and contributed to downward pressures on the Canadian dollar exchange rate. Figure 8 shows the contribution of different factors to changes in Canada's manufacturing cost-competitiveness vis-à-vis the United States over the 1989-98 period. While unit labour costs in Canada fell in relation to the United States (both expressed in $US), this was primarily due to the substantial depreciation of the Canadian dollar over the period. Canada's slower productivity growth is responsible for a loss in manufacturing cost-competitiveness of almost 9 percentage points.

FIGURE 4

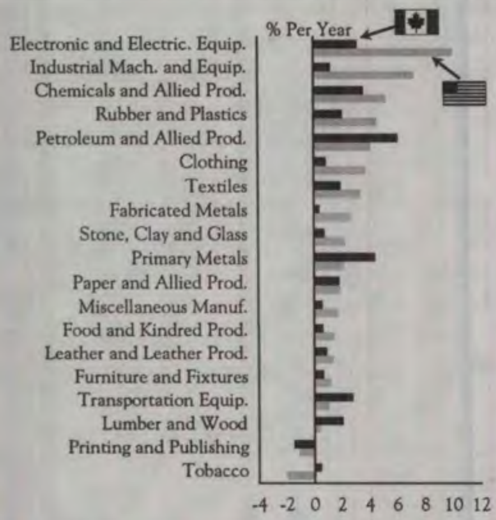
MANUFACTURING LABOUR PRODUCTIVITY* GROWTH



Note: * GDP per worker; U.S. GDP at market prices converted to GDP at factor cost to make it comparable to Canadian data.
Source: OECD, 1998 STAN Database.

FIGURE 5

LABOUR PRODUCTIVITY GROWTH* IN MANUFACTURING INDUSTRIES, 1980-96

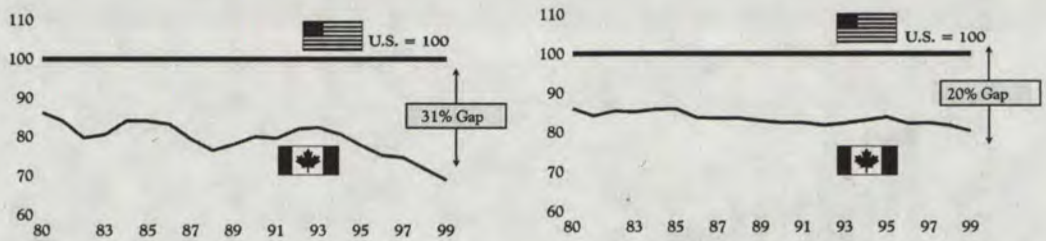


Note: * GDP per worker; U.S. GDP at market prices converted to GDP at factor cost to make it comparable to Canadian data.
Source: OECD, 1998 STAN Database; and industry PPPs from Dirk Pilat *Labour Productivity Levels in OECD Countries: Estimates for Manufacturing and Selected Services Sectors*, OECD Working Paper No. 86, 1996.

FIGURE 6

LABOUR PRODUCTIVITY*, TOTAL MANUFACTURING

LABOUR PRODUCTIVITY*, TOTAL ECONOMY



Note: * Labour productivity for the manufacturing sector is measured by GDP per hour.

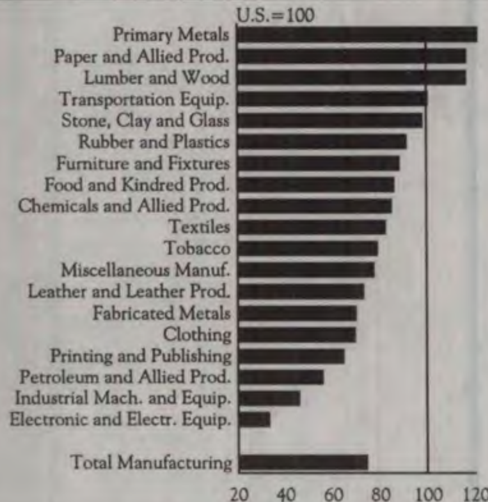
Source: Statistics Canada, U.S. Bureau of Labor Statistics; based on the methodology of the Centre for the Study of Living Standards.

Note: * Labour productivity measured using $1998 GDP per hour.

Source: Statistics Canada, U.S. Bureau of Labor Statistics. Canada-U.S. comparisons are made using range of estimates for purchasing power parity (PPP).

FIGURE 7

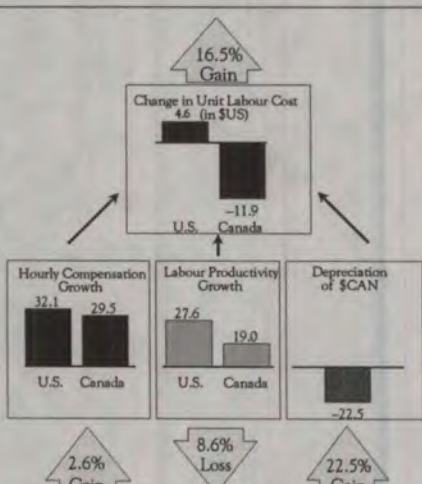
CANADA-U.S. PRODUCTIVITY GAP* IN MANUFACTURING INDUSTRIES, 1996



Note: * GDP per worker; U.S. GDP at market prices converted to GDP at factor cost to make it comparable to Canadian data.
Source: OECD, 1998 STAN Database; and industry PPPs from Dirk Pilat, *Labour Productivity Levels in OECD Countries: Estimates for Manufacturing and Selected Services Sectors*, OECD Working Paper, No. 86, 1996.

FIGURE 8

CHANGE IN COMPETITIVENESS IN MANUFACTURING, 1989-98 (PERCENT)*



Note: * Based on logarithmic decomposition; therefore, growth rates may differ from published growth rates.
Source: U.S. Bureau of Labor Statistics.

INDUSTRIAL STRUCTURE AND THE PRODUCTIVITY GAP

AN IMPORTANT PART OF THE REASON for Canada's slower productivity growth is that this country has been less successful than the United States in shifting resources towards activities with higher productivity and more rapid productivity growth. The contrast between the Canadian and U.S. manufacturing sectors' performances in this respect is most apparent when we compare output trends among industries showing the highest rates of labour productivity growth in the two countries. Figure 9 indicates that, in Canada, despite a flow of resources toward those industries with the highest productivity growth rates during 1980-96, this trend has not been nearly as marked as in the United States. The top 4 U.S. industries in terms of productivity growth expanded at rates that surpassed other U.S. manufacturing industries by several orders of magnitude. In Canada, the top 7 industries ranked by productivity growth experienced above average rates of real output growth, but there was a smaller difference than in the United States between the rates of expansion of high-productivity growth industries and that of other manufacturing industries. While, in the United States, the top-ranked industry in terms of productivity grew much more rapidly than all other industries, in Canada, the industry with the strongest productivity growth, petroleum and allied products, ranked only fourth in output growth.

A number of industries in the United States that experienced very rapid rates of output growth have relatively high productivity levels, and this has provided an additional boost to productivity growth rates in manufacturing. It has also contributed to the disparity between Canadian and U.S. productivity performance, since there has not been a comparable shift of resources in Canada toward manufacturing industries with high productivity levels. This can be seen in Figure 10, where real growth rates of manufacturing industries are arrayed from highest to lowest productivity levels. The concentration of high growth industries at the top of the chart (where productivity levels are highest) is much more pronounced in the United States than in Canada. In contrast to the United States, the two Canadian industries with the highest rates of output growth (transportation equipment, and rubber and plastics) are well down the list based on productivity levels.

In the United States, a central part of the story is the outstanding performance of two industries — electronic and electrical equipment, and industrial machinery and equipment. These two industries, which stand out from other U.S. industries in terms of their relatively high productivity levels and rapid productivity growth, have enjoyed exceedingly strong output growth over the recent past. The rise in importance of electronic equipment and industrial machinery — from 18.5 to 34.8 percent of manufacturing GDP over 1989-97 — has made a major contribution to the recent growth in the U.S. manufacturing sector's labour productivity. As can be seen in Figure 11, these industries, which benefited from major technological and market developments in information and communications technology, did not have anywhere near the same impact on Canadian manufacturing. The productivity performance of Canadian electronic equipment and industrial machinery producers was far below that of U.S. firms in these industries, and also ranked behind that of a number of other Canadian industries.

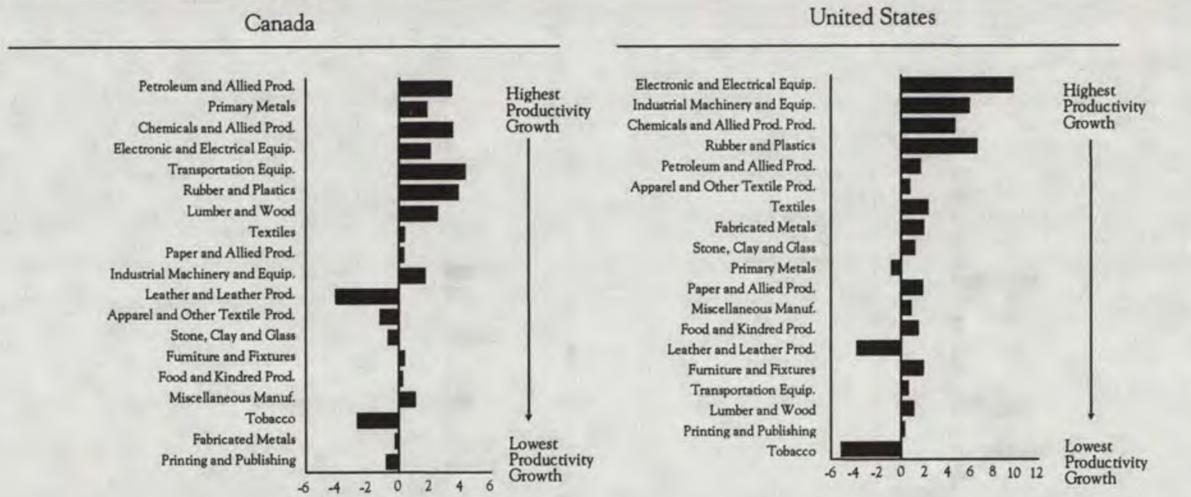
In general, while the United States has concentrated on strengthening its leadership position in a small number of rapidly growing high-technology activities, Canada has experienced a more diversified pattern of manufacturing sector growth since 1980. Capital, labour and intermediate inputs have been reallocated from some traditional industries such as leather products, tobacco products, apparel and textiles, to a range of other Canadian industries, including both those characterized as medium (e.g. transportation equipment, and rubber and plastics) and high knowledge-intensive (e.g. chemicals, and petroleum and allied products) based on their R&D and the human-capital profile of their workers.[5]

By comparing the distribution of manufacturing output across industries, we get a similar perspective on the very different patterns of concentration within the two countries. Indeed, Figure 12 highlights even more clearly that, as compared to the United States, Canadian manufacturing is still heavily focused on resource-based activities. Canadian firms are more productive than their U.S. counterparts in a number of areas of Canadian specialization, including transportation equipment, along with resource-based industries such as lumber and wood, paper and allied products, and primary metals. The relative distribution of U.S. manufacturing output reflects the strength of U.S. firms in high-technology and knowledge-intensive industries, including electronic equipment, machinery, petroleum products, and chemicals and allied products.

Canada has clearly suffered by its inability to participate as fully as the United States in the most dynamic areas of global activity. The cost of Canada's less favourable industrial structure can be approximated by estimating what productivity growth would have been if the structural shifts experienced in the U.S. manufacturing sector had also occurred in the Canadian manufacturing sector. The results of this analysis for the period 1980-96 are shown in Figure 13. If resources had been reallocated within Canadian manufacturing in the same way as in the United States, the average annual rate of labour productivity growth would have been almost 25 percent higher. In 1996, the gap between Canadian and U.S. manufacturers in terms of productivity levels would have been 22 percent rather than 26 percent.

FIGURE 9

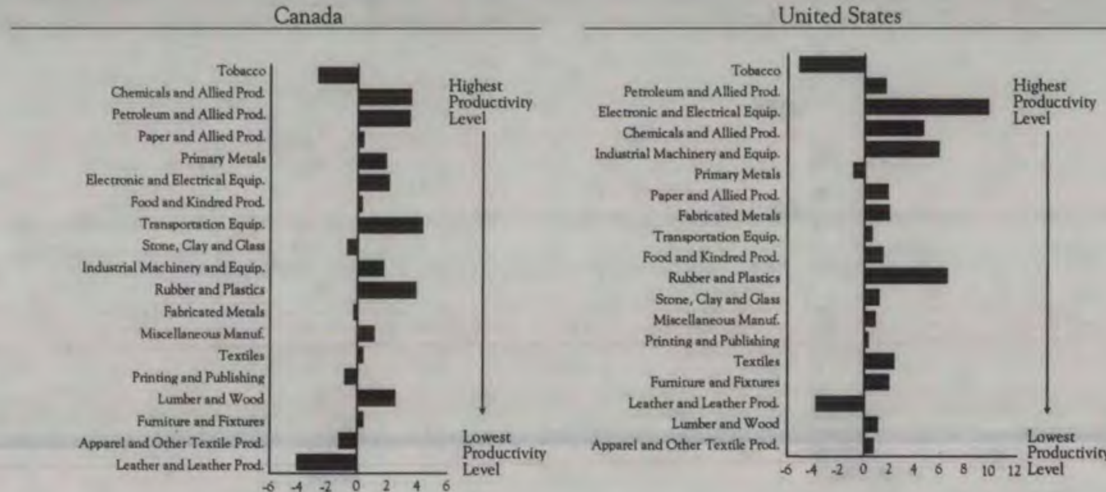
REAL GDP GROWTH IN MANUFACTURING, 1980-96 (RANKED BY PRODUCTIVITY GROWTH)



Source: OECD, 1998 STAN Database.

FIGURE 10

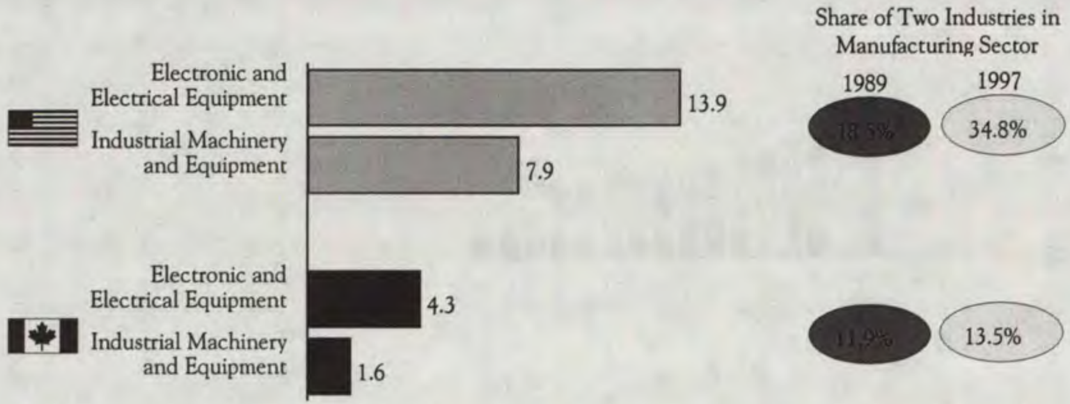
REAL GDP GROWTH IN MANUFACTURING, 1980-96 (RANKED BY PRODUCTIVITY LEVEL)



Source: OECD, 1998 STAN Database, OECD.

FIGURE 11

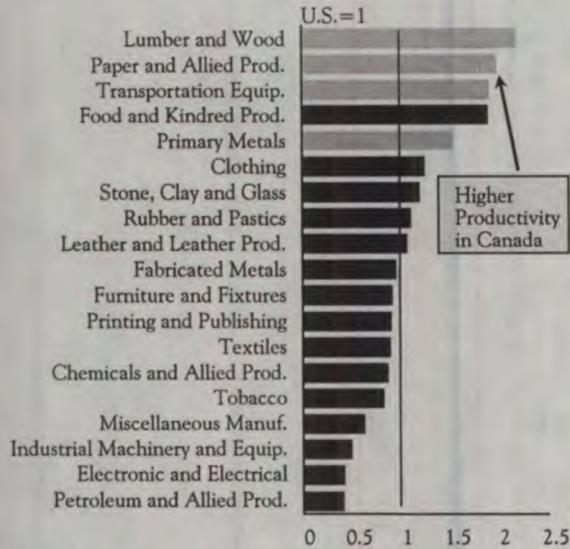
TWO FASTEST PRODUCTIVITY GROWTH INDUSTRIES IN THE UNITED STATES, 1989-97 (PERCENT PER YEAR)



Source: Centre for the Study of Living Standards.

FIGURE 12

RELATIVE GDP DISTRIBUTION IN CANADIAN MANUFACTURING, 1996

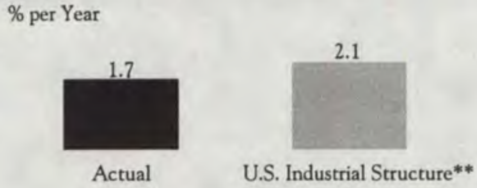


Source: Statistics Canada.

In a recent study, Ed Wolff finds similarly that the industrial structure is a significant, but not the most important, determinant of Canada's lagging productivity performance relative to the United States during the 1980s and 1990s.[6] A major focus of the study is the impact of different patterns of manufacturing specialization on total factor productivity growth in the two countries. The specialization indexes used in the study, which measure the countries' output shares of various commodities relative to the corresponding GDP shares within the OECD, vary less across countries than production shares. Hence, substituting indexes that reflect U.S. specialization patterns for actual Canadian output weights does not have that large an impact on productivity growth. Nonetheless, Wolff finds that, by adopting the U.S. industrial structure, Canada could have raised its rate of total factor productivity growth over 1970-97 by 0.2-0.3 percentage points per year.

FIGURE 13

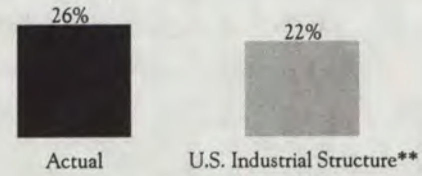
LABOUR PRODUCTIVITY GROWTH IN CANADIAN MANUFACTURING*, 1980-96



Notes: * Average compound growth rate of GDP per worker.
** Growth rate is adjusted according to S. Rao, *An Econometric Analysis of Labour Productivity in Canadian Industries: Some Further Results*, Discussion Paper, No. 134, Economic Council of Canada, 1979.

Source: OECD, 1998 STAN Database.

CANADA-U.S. MANUFACTURING LABOUR PRODUCTIVITY GAP*, 1996



Notes: * GDP per worker; U.S. GDP at market prices converted to GDP at factor cost to make it comparable to Canadian data.
** Assuming a switch in 1980 to the U.S. industrial structure.

Source: OECD, 1998 STAN Database.

UNDERSTANDING DIFFERENT PATTERNS OF INDUSTRIAL DEVELOPMENT

WHY HAVE STRUCTURAL CHANGES not made a more important contribution to productivity growth in Canada? Why has Canada not benefited in the same way as the United States from the strong flow of resources to fast growing manufacturing industries with rapidly improving productivity? To shed light on these questions, it is helpful, first, to recognize that industrial shifts within manufacturing are the net result of the entry, exit and growth of thousands of firms within different sectors of the economy. Second, it is important to understand that the growth of firms depends on their ability to acquire those attributes that underlie competitive success in various areas of activity.

There is data on the first issue — firm entry and exit — from micro-level studies using longitudinal databases. These studies show that, in addition to inducing changes in the industrial structure, firm entry and exit result in significant ongoing changes in the complexion and productivity of individual sectors. Baldwin, for example, finds that over the 1970-79 period, just over 30 percent of the productivity growth in Canadian manufacturing was due to the process of entry and exit. The remainder was the result of productivity growth within plants.[7]

The evidence from micro-economic studies showing that substantial disparities in productivity levels and growth rates exist within, as well as between, industries raises questions about the efficiency of the process of resource allocation in the economy. Canada's productivity growth would improve if there were speedier exit of poor productivity firms and faster entry of new firms with more modern technologies and more efficient production processes. It is unlikely, however, that barriers impeding firm entry and exit are a significant cause of the disparity observed in productivity performance between Canada and the United States.

Over the past three decades, significant progress has been made in dismantling subsidies programs and protective regulations that shielded particular firms and reduced competition in various sectors of the economy. Although Canada does not have a venture capital market as well developed as that of the United States, it has created mechanisms to effectively respond to financial market problems that may impede the commercialization of promising technologies and the start-up of new firms. By and large, Canadian manufacturing firms operate in markets subject to a high degree of domestic and international competition, and firm entry and exit are the result of business decisions made within this competitive market environment.

A better understanding of industrial structure in Canada and the United States is provided by the second factor referred to above, namely, differences among firms in the two countries in terms of the characteristics that are important to competitive success in various areas of activity. This suggests that we can get insights into market structure by looking, for example, at why Canadian firms have not been nearly as successful as U.S. firms in penetrating electronic equipment markets. In the next section, we explore a number of factors that could explain observed differences in competitiveness among Canadian and U.S. manufacturing firms. However, the broad message here is that a strong link exists between industrial structure and productivity growth within firms and within industries. While it is interesting to analytically separate intersectoral shifts from other causes of productivity growth, as we do above, in practice the two are closely related. To understand why industrial growth within manufacturing has followed a different path in Canada than the United States, it is necessary to look at the factors underlying productivity growth and influencing the expansion of Canadian and U.S. firms in various industries.

Our discussion is also based on another understanding of these issues, which it is useful to set out explicitly. In our view, the competitive success of firms and economies depends primarily on the extent of their man-made assets. In the evolving knowledge-based environment, the critical attribute for firms is the ability to generate ideas that will lead to new products and processes. For economies, comparative advantage is less the result of nature's legacy than of the qualities they have developed to make use of this legacy. The latter, in turn, are the result of investments by individuals, organizations and governments in physical and intangible assets. Hence, a discussion of the attributes that determine the competitive success of Canadian firms in various areas and, thereby, that shape Canada's industrial structure, is not simply a comment on the nature of various exogenous factors. Rather, it focuses attention on the decisions made by firms, governments and individual economic actors.

FACTORS INFLUENCING THE COMPETITIVENESS OF CANADIAN FIRMS

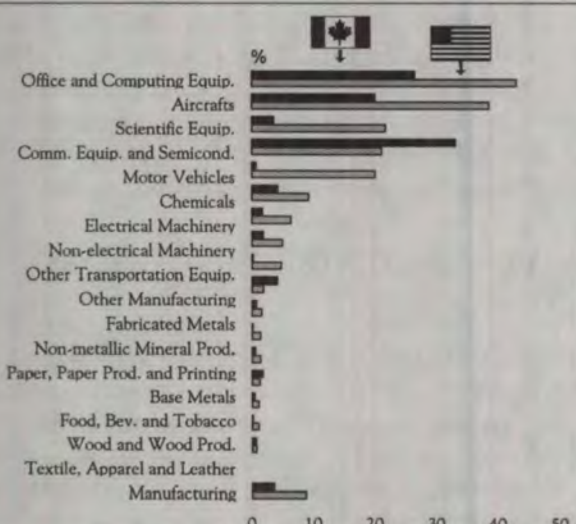
AT THE ROOT OF CANADA'S POOR PRODUCTIVITY PERFORMANCE relative to the United States is this country's failure to adequately transform itself into a knowledge-based economy. Canada's comparative weakness in developing, acquiring and utilizing knowledge goes some distance, we believe, in explaining both the slower labour productivity growth of firms and industries in Canada by comparison to the United States, and the failure of Canadian firms to take significant advantage of the opportunities created in rapidly growing high-technology markets.

Since there are no direct measures of knowledge flows, it is necessary to resort to various proxy measures of knowledge development and use. These are deficient in a number of respects, but particularly because the published statistics are poor at capturing the use of knowledge by firms to achieve minor technical improvements in their products and technologies. Over time, the cumulative impact of minor technological changes that are not included in R&D and related measures can be very significant.[8] Nonetheless, the published data tell a consistent and quite persuasive story about Canadian firms' inferior performance relative to their U.S. competitors along various important dimensions of innovation and knowledge acquisition and use.

Figure 14 depicts the well-known fact that manufacturing firms devote a much smaller share of GDP to R&D in Canada than in the United States. This situation persists in spite of Canada's significantly more generous system of R&D tax incentives,[9] and is observed in virtually all sectors, with the notable exception of telecommunications equipment. In high-technology activities where research is a necessary requirement for participation — such as the production of computer equipment, electrical machinery, aircraft, and scientific equipment — the gap between the Canadian and U.S. rates of R&D investment is very large.

FIGURE 14

BUSINESS ENTERPRISE R&D EXPENDITURES AS A PERCENTAGE OF VALUE ADDED IN MANUFACTURING, 1996-97



Note: * 1996 for the United States; 1997 for Canada.

Source: OECD Science, Technology and Industry Scoreboard, *Benchmarking the Knowledge-based Economies*, 1999.

Elsewhere in this volume, Manuel Trajtenberg shows that Canadian firms' low R&D spending translates into a poor performance in inventive output, as measured by the number of patents received in the important U.S. market. As he discusses, Canada's low ratio of R&D to GDP is particularly troubling, because small countries need to make a larger commitment to R&D if they are to keep pace with larger countries in areas where it is the absolute investment in innovation that determines competitive success. Patent statistics suggest that Canada's innovation infrastructure is poorly developed in a number of leading areas of technological activity.

Canada's weaknesses as a creator of new knowledge are also reflected in a more comprehensive measure of innovative capacity developed by Michael Porter.[10] This innovation index combines a number of measures of R&D quantity (aggregate expenditures on R&D, aggregate personnel employed in R&D) and type (percent of R&D funded by private industry, percent of R&D performed by universities), with an education indicator (share of GDP spent on secondary and tertiary education) and two policy indicators (strength of protection of intellectual property, and openness to international trade and investment). Each measure is weighted according to the results of a regression analysis that estimates the factor's influence on patent activity, and the overall index is calculated on a per capita basis. Although Canada ranks low in terms of per capita R&D spending, it compares favourably with other OECD countries for university involvement in R&D, spending on education, and openness. When the measures are combined, however, Canada ranks only ninth out of the seventeen OECD countries in the 1995 sample, down from sixth in 1980. By contrast, the United States ranked second in 1980, and first in 1995 (Figure 15).

While Canada is well positioned to benefit from the spillovers of U.S. R&D, studies have documented the importance of this form of technology acquisition.[11] Spillovers can only partly compensate for the inadequacy of domestic R&D. A firm's ability to identify and adapt promising new technologies depends on its technological capabilities. Firms that have not developed a strong technological base through investment in R&D are less able to realize the opportunities arising from Canada's proximity to the country that ranks as the world's leading source of new basic and applied knowledge.

Moreover, new technology diffuses with a lag, which is especially problematic for firms competing in markets where product life cycles are highly compressed. In many of the most rapidly growing sectors, including information and communications technologies, and drugs and medical products, firms are under strong pressure to translate new scientific advances into marketable products. Canadian producers cannot compete effectively in these sectors by purchasing technology or waiting for knowledge developed by U.S. firms to spill over the border. To be successful in these fast growing high-technology markets, firms must actively engage in the search for new ways of harnessing advances in basic science.

Canada's relatively favourable access to foreign technical knowledge might be expected to induce a stronger trend towards convergence in the area of process technologies. However, the evidence suggests that some Canadian firms have moved rather slowly to take advantage of new technologies. This problem is present mainly in small and medium-sized enterprises, which have been found to lag significantly behind their U.S. counterparts in the adoption of advanced manufacturing technologies such as computer-aided design (CAD) and engineering systems, numerically-controlled machines, robots, automated handling systems and automatic inspection systems. In 1993, the latest year for which statistics are available, 53 percent of U.S. manufacturing establishments in the 100-to-499-employee range had adopted five or more advanced technologies, compared to only 33 percent of Canadian firms (Figure 16). Moreover, the data indicate that Canadian firms have lagged particularly in the adoption of more expensive technologies offering the potential to exert the largest impact on manufacturing productivity.

Canada's lagging performance in adopting advanced technologies is related to another issue — this country's comparatively low rate of investment in machinery and equipment. Machinery and equipment (M&E) investment is the major vehicle through which new technology enters into the production process. High rates of M&E investment indicate that firms are modernizing their production systems and exploiting the opportunities for improved labour productivity created by new manufacturing technologies. It is therefore troubling to see that Canada has had a much lower M&E investment intensity than the United States over most of the last two decades. While the ratio of M&E investment to GDP has been increasing in recent years, Canada's investment intensity was still 35 percent below that of the United States in 1998 (Figure 17).

Another key element for the development of an efficient knowledge-based economy is a highly educated workforce. While Canada benefits from a comparatively high rate of post-secondary educational attainment, it ranks below many other countries in employer-provided training. Moreover, a number of surveys suggest that technological change has been impeded by shortages of adequately educated and trained workers.[12] Employers in key sectors have reported particular difficulties in finding workers who combine strong technical skills with strengths in other areas, including oral and written communications and management.[13]

FIGURE 15

INNOVATION INDEX FOR SELECTED OECD COUNTRIES, 1980, 1993 AND 1995

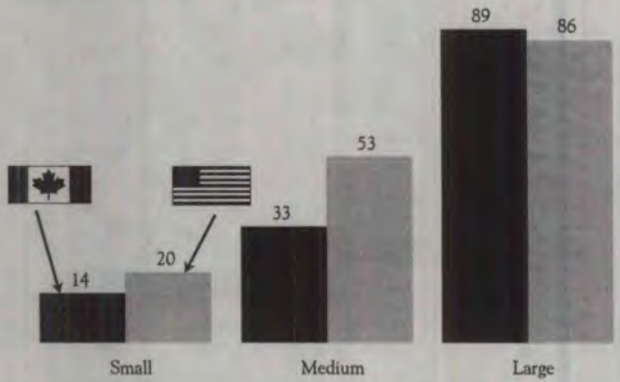
1980	1993	1995
Switzerland	Switzerland	United States
United States	Japan	Switzerland
Germany*	United States	Japan
Japan	Germany*	Sweden
Sweden	Sweden	Germany*
CANADA	Denmark	Finland
France	France	Denmark
Netherlands	CANADA	France
Finland	Finland	CANADA
United Kingdom	Australia	Norway
Norway	Netherlands	Netherlands
Denmark	Norway	Australia
Austria	United Kingdom	Austria
Australia	Austria	United Kingdom
Italy	New Zealand	New Zealand
New Zealand	Italy	Italy
Spain	Spain	Spain

Note: * For 1980, rankings are for West Germany only.
Source: *The New Challenges to American Prosperity: Findings from the Innovation Index*, Council on Competitiveness, Washington (D.C.).

In addition, Canadian firms appear to have been slow to embrace new management and organizational models that are associated with the creation of learning organizations. Case studies indicate that corporate strategies fostering creativity, flexibility and information-sharing tend to yield significant payoffs.[14] In more successful firms, changes in organizational arrangements and human resource practices are often part of restructuring efforts aimed at realizing the potential from investments in advanced technologies. Studies suggest, however, that Canadian firms have been hesitant to adopt innovative human resource practices, and that they invest much less in soft technologies than in hard technologies. In one recent survey, 70 percent of the respondents were judged to be "traditional" in their human resource practices.[15] In the 1999 report of the World Economic Forum, U.S. business ranked first in management approaches and strategy, while Canadian business only ranked 12th.

FIGURE 16

PERCENTAGE OF FIRMS USING AT LEAST FIVE ADVANCED TECHNOLOGIES, 1993



Note: Small=20-99 employees, medium=100-499 employees, and large=500 or more employees.
Source: Statistics Canada.

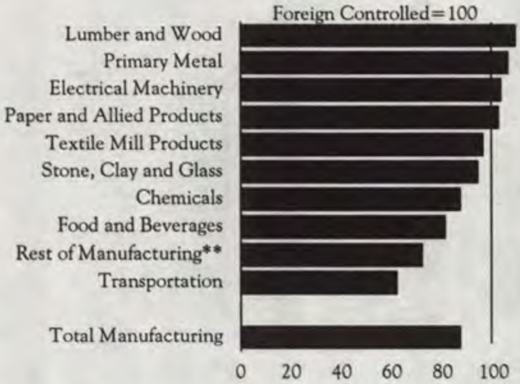
FIGURE 17

INVESTMENT IN MACHINERY AND EQUIPMENT

Source: Statistics Canada, BEA.

FIGURE 18

PRODUCTIVITY* OF CANADIAN-CONTROLLED FIRMS BY SECTOR, 1993-95



Notes: * Labour productivity.
** Includes tobacco; furniture and fixtures; printing and publishing; leather industries; and other manufacturing.
Source: J. Tang and P.S. Rao, *Are Canadian-Controlled Manufacturing Firms Less Productive than their Foreign-Controlled Counterparts?* Working Paper, No. 31, Industry Canada, 2000.

Some significant structural differences have affected the relative performance of the Canadian and U.S. manufacturing sectors. Foreign affiliates have a much larger role in Canada's manufacturing sector — accounting for over 50 percent of output, as compared to fewer than 20 percent in the United States. The evidence suggests, however, that foreign-controlled firms have, on the whole, made a positive contribution to Canada's manufacturing performance. Data for the 1993-95 period indicate that foreign-controlled manufacturing firms were, on average, 13 percent more productive than Canadian-controlled firms (Figure 18). This superior performance is not due to differences between foreign and domestic firms in size or market structure.[16] It likely reflects in part the greater success of foreign-controlled firms in building a capacity for efficiently acquiring and utilizing knowledge.

Another difference is that small firms are much more important in Canada than the United States. Figure 19 provides an indication of the significant differences in the size of firms in the manufacturing sectors of the two countries. While small firms are often the source of radically new technologies and have a flexibility that allows them to be more responsive than large firms to changes in market conditions, they can be significantly disadvantaged by their inability to exploit available economies of scale.[17]

FIGURE 19

SHARE OF MANUFACTURING OUTPUT AND EMPLOYMENT BY ESTABLISHMENT SIZE IN CANADA AND THE UNITED STATES, 1992

Source: Statistics Canada and U.S. Census Bureau.

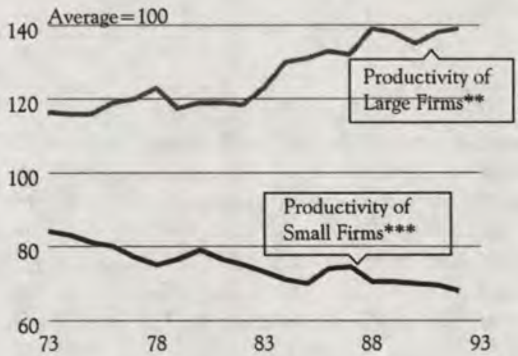
As can be seen in Figure 20, small manufacturing firms are indeed much less productive than large firms. Moreover, over the years, the productivity gap between small and large firms has widened considerably. The continued importance of small firms in Canada's manufacturing sector has thus slowed productivity growth and, in the process, contributed to this country's failure to develop a more favourable industrial structure.

CONCLUSION

GIVEN THE IMPORTANCE of a strong manufacturing sector to the health of the Canadian economy, that sector's poor productivity performance relative to the United States since 1980 is of concern. Lagging productivity growth is impeding the competitiveness of the Canadian manufacturing sector and contributing to the downward pressure on the Canadian dollar exchange rate. Part of the reason for Canada's slower productivity growth is that this country has been less successful than the United States in shifting resources towards activities with higher productivity and more rapid productivity growth. While the United States has enjoyed the benefits from a much-increased concentration on dynamic sectors — especially electronic and electrical equipment, and industrial machinery and equipment — Canada has experienced a more diversified pattern of development. As compared to the United States, this country

FIGURE 20

PRODUCTIVITY* LEVEL BY FIRM SIZE, CANADA



Notes: * Census value added per worker.
** Firms with more than 500 employees.
*** Firms with number of employees between 1 and 100.

Source: Baldwin, John R., *Were Small Producers the Engines of Growth in the Canadian Manufacturing Sector in the 1980s*', Statistics Canada Research Paper No. 88, 1996, and U.S. Census Bureau.

is still heavily dependent on resource-based manufacturing industries that are characterized by relatively moderate rates of productivity growth.

The different pattern of sectoral growth in Canada is not due to barriers that have impeded the reallocation of resources. By and large, Canadian manufacturing firms, like their U.S. counterparts, operate in competitive markets where commercial opportunities dictate entry and exit decisions. Rather, the different structural patterns reflect the problems Canadian firms have experienced in attempting to build markets in rapidly growing high-technology sectors. This, in turn, is a result of the apparent failure of Canadian firms to acquire the attributes that lead to success in knowledge-based activities. Since these same factors account for the productivity differences observed between Canadian and U.S. firms in similar industries, there is a link in practice between industrial structure and other causes of Canada's lagging productivity performance.

The factors that appear to be limiting the growth of innovative, knowledge-based enterprises include Canadian firms' limited investments in R&D, their slowness in adopting advanced technologies, their relatively low M&E investment intensity, their relatively modest investment in employee training, and their reluctance to implement new management models that promise to improve corporate performance. The performance of U.S. firms is significantly better in most of these areas. If Canadian firms are to participate more fully in the most rapidly evolving and growing areas of global commerce, Canada must make the investments required to build a comparative advantage in high-technology, knowledge-intensive activities.

ENDNOTES

1 This is discussed in Rao (1979), Rao and Preston (1984), and Daly and Rao (1985).
2 Rao and Lemprière (1992).
3 This issue was the subject of a recent presentation by Jack Triplett of The Brookings Institution. See Triplett (1999).
4 The lack of comparability in published Canadian and U.S. measures of total factor productivity is discussed in the study by Serge Coulombe elsewhere in this volume.
5 This is based on the classification scheme used in Lee and Hass (1996).
6 Wolff (2000).
7 Baldwin (1995).
8 Baldwin, for example, has shown that growing small and medium-sized Canadian enterprises undertake considerable innovative activity that is not considered formal R&D. See Baldwin (1994).
9 For example, Jacek Warda finds that, in 1998, the after-tax cost of $1 of R&D investment for a large manufacturing firm was 0.482 in Quebec and 0.507 in Ontario, as compared to 0.521 in California. See Warda (1999).
10 Porter and Stern (1999).
11 Bernstein (1998).
12 The evidence is reviewed in Betts (1998).
13 The source is the HRDC Expert Panel on Skills.
14 The literature is reviewed in Newton and Magun (2001).
15 Betcherman et al. (1994).
16 This is based on Tang and Rao (2002).
17 This is partly based on Morck and Yeung (2002).

ACKNOWLEDGEMENTS

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6

Determinants of Canadian Productivity Growth: Issues and Prospects

SUMMARY

IN THIS STUDY, WE DISCUSS THE FUTURE of productivity growth in Canada. Given the high profile of the productivity debate in the last year, what was once a relatively arcane subject to most people is now daily grist for the editorial and business pages of our newspapers. Talk of a productivity crisis and various counterpoints to this argument have become commonplace. In this chapter, I will try to step back somewhat from the current debate and take a broader look at what economists know, or think they know, about productivity growth, and how this knowledge might shape our views about the future for economic growth in Canada. Obviously one cannot know with any great certainty what the future will bring. Nevertheless we can say with somewhat more precision what are likely to be important potential developments, either positive or negative for productivity growth and thus living standards in Canada. The paper will first review the theory and empirical evidence and then go on to a forward looking perspective on productivity growth in Canada in the coming decades. Finally, I will offer some opinion as to how productivity considerations should enter in the formulation of economic policy.

The organization of the paper is as follows. The section entitled *Productivity Growth: Why do we Care?* discusses some of the basic theory and measurement issues, with references to the recent Canadian and international debates on productivity. Two themes are covered. First, the link between productivity and living standards. Here we draw out the links between other determinants of living standards such as labour force participation and terms of trade changes, with an emphasis on productivity growth as the most important long term permanent determinant of living standards. Second, a discussion of the relationship between theory and measurement in light of the widespread use of the concept of multifactor productivity, and lastly a review of the on-going measurement debate

as to whether and how well economists can actually measure outputs and inputs. The section entitled *Productivity Drivers and Levers* turns to a discussion of the empirical literature on the "determinants" (correlates) or drivers of productivity growth including investment, education and training, innovation, diffusion, and the broader context in which productivity growth is set. The next section, entitled *Productivity Growth in the 21st Century*, deals with the prospects for future productivity growth in Canada over the next couple of decades. This section is largely speculative in nature drawing on what we know from economic history and the recent contributions of the endogenous or "new" growth literature. It includes a discussion of a number of important external and domestic developments in the Canadian and global economies. The last section concludes with a discussion of how traditional economic policies should account for potential productivity effects.

PRODUCTIVITY GROWTH: WHY DO WE CARE?

PRODUCTIVITY IS ROUGHLY SPEAKING A MEASURE of how effectively the resources of an economy are translated into the *production* of goods and services. Over long periods of time, productivity is the single most important determinant of a nation's living standard or its level of real income. This relationship for a cross-section of countries is illustrated in Figure 1 which plots real wages, a fairly conventional measure of real income, against labour productivity. We make a distinction between the level of productivity in the economy at a point in time, and the changes in the level of productivity or productivity growth rate. It is common to discuss both of these without making clear which concept is being used. Productivity *levels* are related to the standard of living in a country, and productivity *growth rates* are the major determinant of the rate of increase in living standards over time. In Figure 2, Canadian real wages and labour productivity are shown from 1961 to 1998. It is evident the two are strongly related over time.

Productivity, living standards and income are however slightly different concepts and it is useful to consider more closely how they are related to each other. To make the connection with living standards we need to make the links between the production side of the economy and the way in which production determines income. In most western economies, income is generated in factor markets; it is the value of the services of labour and earnings of assets that occur as a consequence of supplying these factor services to producers of goods and services (either the private or the public sector). The wages and profits that result reflect a combination of (a) the value of the particular goods and services produced, and (b) the productivity of the factor inputs in producing those goods and services. Income from a *given* supply of labour and capital can rise

FIGURE 1

WAGES AND PRODUCTIVITY ACROSS COUNTRIES, 1993

Note: * In manufacturing.
Source: Industry Canada compilation based on data from *International Yearbook of Industrial Statistics*, 1998.

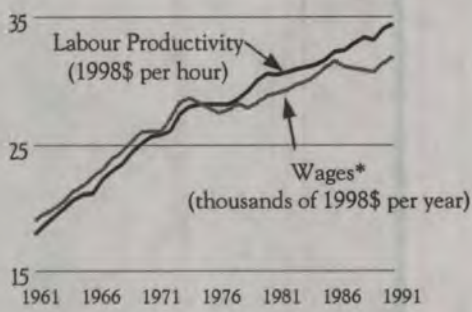
because either (a) the value of the goods produced rises or (b) the productivity of those factors has risen. Higher productivity means that more goods and services can be derived from the same factor inputs.

The distinction between the effect of prices on factor income and the productivity effect is often confused. Productivity growth in the sense that more is produced with less can have important price effects in the market as the supply of the goods produced increases; these supply effects can in turn affect incomes and real purchasing power. Productivity improvements often result in lower prices, which benefit consumers, but which may or may not raise the incomes of those producing the goods in question. In an economy such as Canada's, which participates heavily in international trade, this means that what we produce is generally not the same as what we consume. Hence if what we produce goes down in price and what we consume goes up in price then living standards will fall, holding productivity, as conventionally measured, constant.

Living standards refer to the real value of consumption that a given real income will purchase. The differences between consumption and production activities however can create some problems in making the connection between living standards and incomes. An economy in which income is high but much of that income goes into investment will be generating a lower level of consumption

FIGURE 2

WAGES AND PRODUCTIVITY IN CANADA, 1961-98



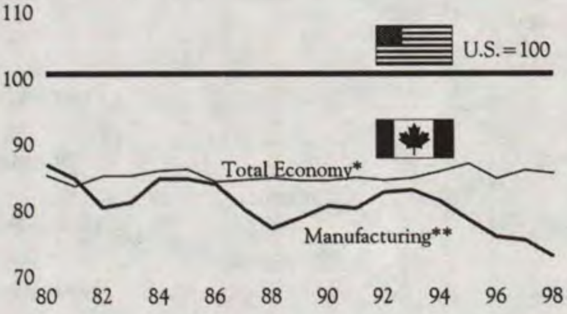
Note: * Real producer labour compensation (wages/salaries plus benefits) per worker.
Source: Industry Canada compilation based on data from Statistics Canada.

that would otherwise be the case. I will not take up these issues here except to note that when looking at long term economic growth it is possible that productivity will vary as a direct consequence of the decision to consume versus invest. Often the decision to be 'more productive' involves a choice to defer consumption to the future. To that extent, becoming more productive can be coincident with a reduction in real living standards as measured by what we consume. Clearly, the best kind of productivity growth is the kind that does not require a sacrifice of current consumption.

National productivity statistics are commonly used to make international comparisons, both in terms of levels and in terms of growth rates. In Canada, the comparison with the United States our closest neighbour and largest trading partner is the one most familiar to people. Generally, productivity growth rates in Canada seem similar to those in the United States. Nevertheless there still appears to be a productivity gap between Canada and the United States in terms of *levels*, as illustrated in Figure 3. This figure also illustrates that the "productivity gap" seems to be getting worse in the manufacturing sector. Looking at productivity levels, across countries in Figure 4, we see that Canada in 1996 appears in the middle of the OECD pack, with the United States still the lead country. As will be discussed in this paper there are a number of debates both on the interpretation of these statistics, and on the theories explaining these "gaps" and what policies might lead to their reduction.

FIGURE 3

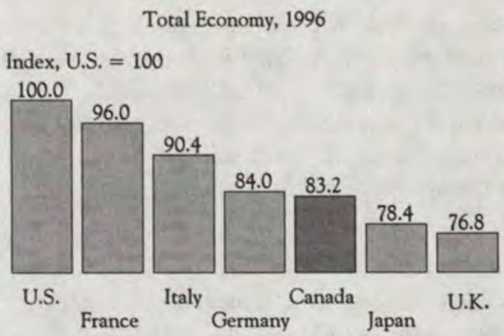
PRODUCTIVITY LEVELS



Notes: * Labour productivity measured using $1998 GDP per hour.
** Labour productivity for the manufacturing sector is measured by GDP per hour, based on the methodology of the Centre for the Study of Living Standards.
Source: Industry Canada compilation based on data from Statistics Canada and U.S. Bureau of Labor Statistics.

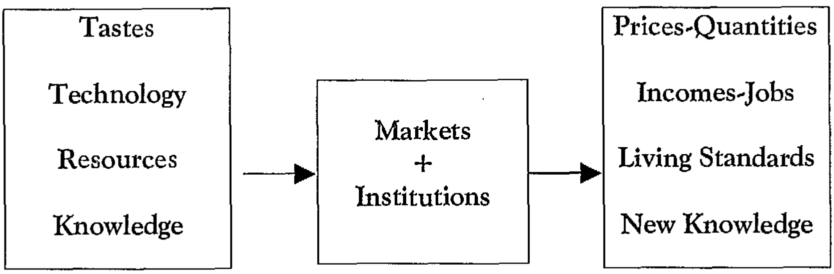
FIGURE 4

PRODUCTIVITY LEVELS*



Note: * Output per worker.
Source: OECD, *Science, Technology and Industry Outlook*, 1998.

The study of productivity growth tends to be compartmentalized into three different sub-disciplines each with their own perspective. One most familiar to non-economists is associated with the writings of economic historians such as Nathan Rosenberg. It takes a broad system or economy-wide approach to productivity in which markets and institutions play a key role and is depicted in the following schematic.



Explanations ranging from the role of institutions such as the rule of law, public health, communications and transport innovations, industrial innovations and of interest-group politics and rent-seeking, cultural differences and numerous others are offered. These wide-ranging accounts are undoubtedly both valid and important and find some counterparts in the empirical evidence discussed below. A second group of scholars uses what might be called the macro-economic growth perspective, and is reflected in the writings of people such as Robert Solow and Raul Romer. There is a reliance in this approach on more formal modeling, quantitative analysis, and often medium-run perspective — that is, they tend to think in terms of decades rather than centuries. Also, much of this literature is not concerned with the question of what causes the transition from pre-industrial to industrial economies. This approach tends to employ traditional supply and demand explanations for economic growth relevant to a modern mixed economy with substantial public and private sectors. Factors that enter the analysis include:

A. Supply side growth factors:

- primary inputs (labour, resources);
- re-producible capital goods (physical and human capital);
- technology/management/knowledge base;
- allocative efficiency of markets/external spillovers;
- international comparative advantage;
- terms of trade;
- public policy.

B. Demand-side factors:

- external market access;
- global business cycle;
- domestic macroeconomic policy.

'Productivity' emerges from the supply- and demand- side integration in a number of different ways, but generally speaking we can think of productivity — i.e. the efficiency with which inputs are transformed into useful outputs — as a summary statistic of the performance of the entire system. Public policy implications almost always follow from an analysis undertaken in this perspective.

A third group of scholars focuses primarily on the measurement side of the debate and is represented by people such as Erwin Diewert of University of British Columbia and Zvi Griliches of Harvard University. They are concerned with the way in which inputs and outputs are measured, how they might be mis-measured, and various ways in which productivity statistics can be constructed and compared both over time and between countries, industries, and firms. Generally speaking the measurement school of productivity is primarily if not exclusively empirical and uses a framework based on the concept of the neoclassical production function. They tend not to focus on theorizing about the determinants of productivity growth, nor is their research concerned with either system-wide, general equilibrium or large-scale institutional explanations of productivity change. Measurement is however extremely important and we turn now to a discussion of the way in which productivity statistics are constructed and used in the debate.

MEASURING PRODUCTIVITY

PRODUCTIVITY STATISTICS ARE INDEX NUMBERS of the resources used in the economy's production activities relative to the output of those activities. We usually define this as a simple ratio:

$$\text{Productivity} = \frac{\text{Quantity of Output}}{\text{Quantity of Input}}$$

This definition is made operational by statisticians in a number of ways. At the level of both the individual firm and the economy, the most common productivity measure is average labour productivity. Thus, if X is a measure of output and LAB is a measure of labour input, *average labour productivity* is given by:

$$\text{Average labour productivity (ALP)} = X/LAB.$$

At the level of the individual country, by far the most common statistic used in doing economic growth calculations or international comparisons is *real GDP per capita*, which is the economy analogue to the ALP concept. Let Y denote real GDP (we get to the issue of measuring this variable later) and Pop the population. Then real GDP per capita is defined as:

$$r = \frac{Y}{Pop}$$

As a productivity measure this variable does not a make lot of sense because (a) what fraction of the population the economy allocates to production can be quite different than simply counting the population, and (b) there are a lot of factor inputs other than "people" that go into production. In many cases, it is used as a measure of living standards. It is useful to note how productivity and other factors affect this widely used statistic.

Productivity and Real GDP per Capita Indexes

1. *Labour force participation.* A common correction is to adjust the population by the number of people who are employed. Let e be the employment population ratio L/Pop, where L is the labour force, then GDP per worker is often reported as:

$$r_W = \frac{Y}{L} = \frac{Y}{ePop}.$$

Note that holding r constant, GDP per worker will change with changes in the number of employed persons, or for a given labour force, with the labour force participation rate. Higher labour force participation may or may not be a good thing from the point of view of ultimate social well-being.

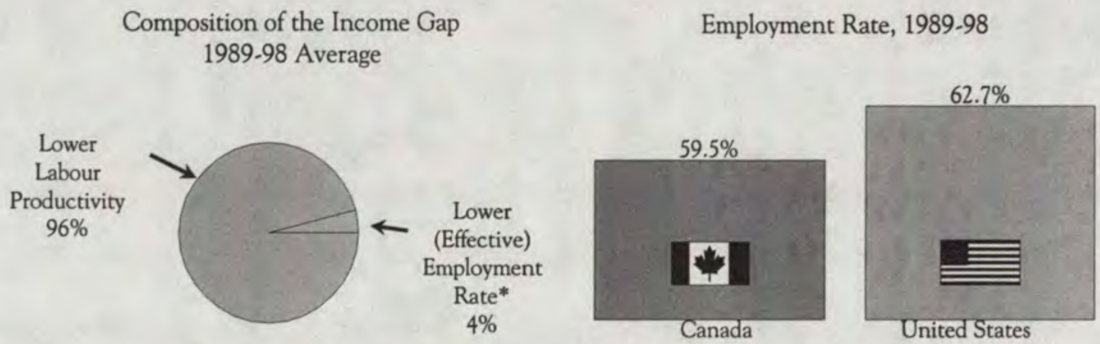
In Canada-U.S. comparisons of economic performance, it is often claimed that the per capita real income gap is due to higher unemployment or a lower employment rate in Canada. Figure 5 indicates however that most of the real income gap is due to differences in productivity rather than to differences in the employment rate.

2. *A further refinement is to correct for the number of hours worked.* This has become more common with large shifts to part-time work and substantial international differences in average hours of work. Let H be the total hours worked and h the average hours worked per person employed. Then, we define GDP/hour as:

$$r_H = \frac{Y}{H} = \frac{Y}{hL}.$$

FIGURE 5

SOURCES OF THE INCOME GAP BETWEEN CANADA AND THE UNITED STATES



Note: Total hours worked per capita, based on PPP=0.85.
Source: Industry Canada compilation based on data from Statistics Canada, U.S. Bureau of Economic Analysis and OECD.

Source: Industry Canada compilation based on data from Statistics Canada, U.S. Bureau of Labor Statistics, and U.S. Bureau of Economic Analysis.

This index is very close to a measure of average labour productivity at the economy-wide level, and thus receives a lot of attention. Note that GDP per capita can go up if people work longer hours, but strictly speaking this does not correspond to an increase in "productivity" as measured by r_H. Both the hours correction and the labour force participation correction bedevil productivity comparisons across countries and over long periods of time. The absence of good comparable data often forces one to rely on the more commonly used r variable than a true productivity index. The history of economic growth is one in which hours of work have been reduced and this is generally regarded as a good thing. Many international comparisons fail to make this correction. Hours of work for example are much longer in the United States than in Germany, and thus comparisons of GDP per capita between Germany and the United States make the United States appear to have higher real incomes, while a productivity comparison shows Germany to be very close and by some measures better off than the United States. On the other hand, the economic performance of a nation is often judged in terms of its ability to generate employment either in terms of job numbers or hours of work. As we shall see the connection between productivity and employment is quite complex, and both productivity and employment are endogenous to the economic system. A crucial issue is whether there is a long-term trade-off between employment and productivity, or alternatively whether higher productivity is necessary for greater employment.

Getting Sophisticated: Multifactor Productivity

It has long been recognized that the notion of inputs must go beyond the simple labour input, although how this is done remains one of the most contentious areas in economics and relates to the problem of how to treat investment and technology. Suppose that there are two factor inputs — hours of work, H, and a single index of capital goods used in production, K. The purpose is to define an index that can measure how much output growth is *not accounted for* by changes in H and K. This index is called the multifactor productivity (MFP) growth. Let $F(H,K)$ be an index of resources used in production — it is critical that this index be time invariant (or geographic invariant if we are doing comparisons across space). The level of multifactor productivity is defined as the index A given by the ratio:

$$A \equiv \frac{Y}{F(H,K)}.$$

Many economists think of changes in A as being the 'true' or correct measure of productivity change. This view derives from the traditional neoclassical theory of production which takes technology as exogenous at a point in time, and all markets are assumed to be competitive. In this case, F is identified as the time invariant portion of a firm's production function. This leads to the famous Solow growth accounting equation (actually developed by Tinbergen in the 1930s) which gives an equation for *the growth rate of* MFP, (GMFP).

$$GMFP \equiv \frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta H}{H} - (1-\alpha)\frac{\Delta K}{K}$$

where α is the cost share of labour in total costs, or at the national level the share of wages in total national income. This equation is one of the most famous in economics and is often referred to as the "Solow residual calculation:" In words,

> *The growth rate of* MFP *equals the growth rate of output less a weighted sum of the growth rates of capital and labour inputs, where the weights on each factor input correspond to their shares in the cost of producing the output* Y.

MFP statistics are now routinely reported by statistical agencies including Statistics Canada. Long-run average MFP annual growth rates vary from 0 to 2 percent historically. The interpretation of these numbers however remain controversial. It is essential to remember that as a simple matter of measurement, GMFP is defined as a residual — i.e. it is that portion of output growth that cannot be accounted for by input growth.[1]

WHAT'S GOOD ABOUT THE MFP GROWTH RATE?

ONE IMPORTANT MOTIVATION for looking at MFP rather than the simple growth rate of labour productivity is the essential role of capital accumulation in the economy. Let G (x) denote the annual growth rate of any variable x. The average growth rate of labour productivity under the 'normal assumptions' is given by:

$$G(r_H) = G(A) + \alpha\, G(K/H)\,.$$

Thus real output per hour can increase either because MFP growth has occurred or because capital per hour worked has increased. It is important to note that these normal assumptions include an absence of spillovers, or equivalently the perfect correspondence between market prices and social costs.

In practical measurement terms, accumulation will tend to be more important in explaining average labour productivity growth the greater the share of "capital" given by the parameter α. For years this share was identified with the share of profits in national income at the aggregate level — approximately one third for most advanced economies. Recently this conventional wisdom has been called into question by those who argue that inclusion of human capital, which is also subject to long-term accumulation, brings this number closer to two thirds.[2] The debate is more than academic. With very high shares of "capital" in national income, changes in investment rates can have sustained and long-term effects on growth rates of productivity even in the absence of technological change. This is in sharp contrast to economies with low capital shares; in these economies, the law of diminishing marginal productivity quickly limits the growth effects of additional investment. Higher investment can lead to higher income levels but not to permanently higher growth rates.

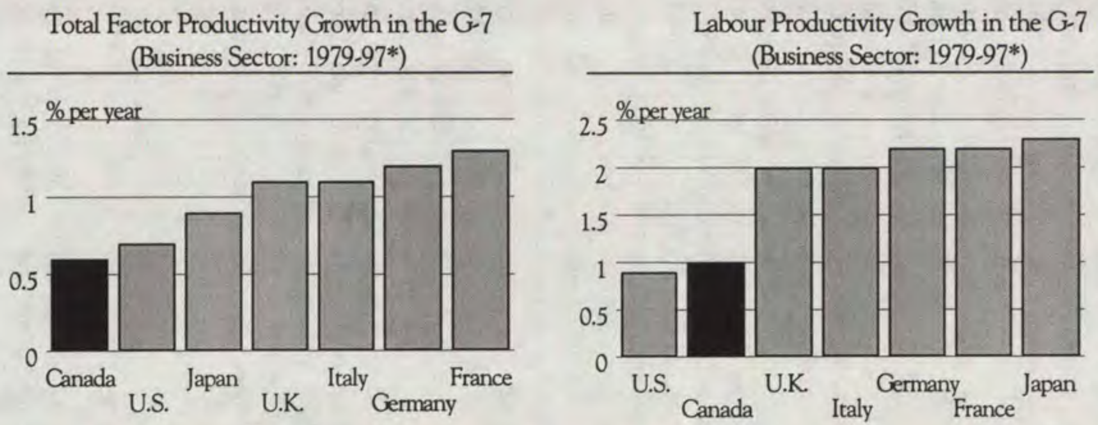
If the capital share is quite high low productivity growth may be due to either low rates of MFP growth, or to the fact that investment (in a comprehensive sense) is too low. There has been a vigorous debate for example in this tradition on the role of public capital infrastructure in productivity growth, and the possibility that low productivity growth is due to low rates of investment in public infrastructure, such as roads, bridges, sewers, etc.

In many countries and in certain periods of industrial development the "capital deepening effect" has been thought to be very important. A good example is the recent controversy on East Asia. Alwyn Young's[3] work challenged the view that Asian growth rates represented substantial technological upgrading; he did this by showing that much of the high growth rates were obtained by increases in capital per worker associated with high investment rates. Going back to our discussion of investment versus consumption, if high labour productivity comes about through capital deepening effects this is not necessarily welfare-improving since investment can only occur at the expense of consumption.[4]

It turns out that for industrial countries, most of the change in measured labour productivity appears to be strongly related to total factor productivity (TFP) growth rates. In Figure 6, the 1979-97 growth of both average labour productivity and TFP for the G-7 countries are shown as calculated by the OECD. It also illustrates the low ranking of both Canada and the United States in terms of productivity growth relative to Japan and the European countries. The sources of this divergence in productivity statistics remains a hotly debated subject and part of this debate pertains both to the interpretation of TFP statistics and to more complex measurement issues.

FIGURE 6

PRODUCTIVITY GROWTH IN THE G-7 COUNTRIES



Note: Or the latest year available: 1996 for Japan, France, Italy and the United Kingdom
Source: OECD, December 1998; OECD Economic Surveys, Canada, 1999.

MFP and Technological Change: Are They the Same Thing?

THERE ARE MANY WHO TAKE THE VIEW that MFP is not a useful measure of technological change because new technology is inherently embedded in new goods and thus one cannot identify technological change independent of the measurement of these goods either as inputs — say in the case of a computer — or as outputs, as in the case of a new drug. There is an older literature which tries to correct within an exogenous technological change framework for the "vintage effect;" if new technology is embodied in new capital goods then higher rates of investment will tend to be associated with higher rates of observed productivity change. Correcting MFP calculations for vintages effects is a complicated business. A recent effort on Canadian data is an Industry Canada study by Gera, Gu and Lee (1998). Recent work using quality change in computers and other electrical/electronic capital goods lends some credence to the view that these corrections are very important at the aggregate level. Greenwood, Hercowitz and Krusell (1997) for example argue that much of the infamous productivity slowdown is in fact a "measurement problem" on the input side and that much of the post-1974 technological slowdown as measured by slow MFP growth can be explained by inappropriate measures of the change in capital, K.

A lot of work has been done to extend the same type of arguments to human-resource inputs in the form of what economists call "human capital." Economic growth in virtually all countries has been characterized by substantial increases in the level of educational attainment and in resources devoted to education and training of workers. It is thus argued that H should be replaced by an index of labour services $S = \theta H$, where θ is some index of the average quality of the skills applied to hours worked. The important point is that education and training policies involve investments in human capital which are durable and thus lasting. That is θ increases slowly and as a consequence of conscious policy and investment decisions. When these corrections are made what happens to MFP growth? Not surprisingly growth attributable to "pure" MFP declines due to the skill upgrading that has occurred in the labour force. But can one seriously take the view that skill upgrading is not real productivity change? This leads us to the next topic.

The Measurement Debate

IN THIS SUBJECT MEASUREMENT IS EVERYTHING. Much of the disagreement on the "facts" follows simply from the fact that measuring both output and factor inputs is becoming increasingly difficult, both conceptually and in practice.[5] In the face of this disagreement, the debate tends to be less constrained by indisputable "facts." The measurement problems on the output side pertain both to comparisons across time and across space. In services there are well known problems in areas such as retailing where margins have been the conventional output measure. Yet we know that increased competition has led precisely to a reduction in these margins, but in any reasonable sense "output" in retailing has not declined. Increased quality and variety of goods has been a major source of economic growth, yet we know these are generally not accounted for in output statistics. International comparisons are fraught with difficulty even in traded goods industries. Baily and Gersbach (1996) report how product mix differences between plants across countries can severely distort price deflators used in fairly narrow industrial classifications. Just how important is all this? To put it in context we have the Nordhaus (1996) argument that with appropriate quality adjustments to the CPI for new goods, real wages over the last century would have increased 40 to 190 times rather than the reported 13-18 fold increase. Others argue that with respect to the productivity slowdown, only a small fraction can be explained by measurement — around 0.2 percentage points.

The general issue of economic growth based on quality change rather than quantity change poses some serious problems for growth economists and policy-makers. Not the least of these is simply that the traditional concept of the price level as a nominal measuring stick becomes increasingly difficult to defend. The 1986 Bureau of Labor Statistics adjustments to computer prices is a good example. Suddenly, the official statistical view was that computer prices had been declining at 15 percent per year, rather than the previously reported flat numbers. This led to serious revisions in a wide range of other statistics and changed the magnitude of the estimated productivity slowdown. As we shift to a knowledge-based economy, it is reasonable to expect that a much larger fraction of economic growth will be quality growth rather than quantity growth. After all just how many cars or computers or heart bypasses do you really need? As economic growth is increasingly quality based, concepts such as potential output will be increasingly difficult to define and quantify. Policy-makers will be faced with a much wider range of estimates of "real output growth" both in the past and in the future.

Ignoring for the moment how new goods come into being, we know that much of the process of economic growth is associated with the introduction of new goods, and statistical procedures to correct for these changes are very imperfect, and in many cases not carried out at all. The debate on CPI revisions in the United States has focused on these issues extensively.[6] If GDP is mismeasured and there are good reasons to believe it is then MFP will be low. This problem is thought to be particularly severe in service industries, but my own view is that manufacturing has many of the same problems as the boundaries between manufacturing and services blur. Griliches (1992) notes that the unmeasured sector (services) now accounts for most of what appears in the national accounts and is the same sector which has the lowest MFP growth. He does not think this is a coincidence.

On the input side there are similar problems, particularly with respect to human and physical capital. The difficulties here relate directly to the debate as to whether MFP is a useful measure of technological change. There is a host of critics of MFP, including Richard Lipsey (1996), who take the view that since so much of what we think of as technological change involves the transformation of both the nature of the outputs and the inputs, then measuring it by a residual calculation as done in MFP accounting is meaningless.[7] Common reasoning certainly would seem to support this view, but the counter argument is that economics by definition is full of index number problems and technological change is just one more of these. Measured MFP growth must occur if real living standards are to rise, and furthermore most of the available evidence points to a strong correlation between MFP and real income measures. This alone suggests that the concept should be taken seriously.

POLICY: DOES IT MATTER HOW WE MEASURE PRODUCTIVITY?

THE PRODUCTIVITY MEASUREMENT LITERATURE REFLECTS a substantial tension between those who view productivity growth as the outcome of rational maximizing investment decisions by firms and individuals, and those who view productivity change as resulting primarily from endogenous changes in technology, which in turn are a consequence of the growth of knowledge. The former group is identified closely with the Jorgenson school of TFP measurement. Generally their approach is to adjust factor input for quality change which has the effect of reducing the residual. For example if the labour input is disaggregated into skilled and unskilled, then as skill upgrading occurs this shows up as an increase in the skilled input and a decrease in the unskilled. Since the skilled workers earn higher wages, weighting factor input growth rates by cost shares has the effect of increasing the measured rate of aggregate input growth and thus reducing the residual MFP number.

The "non-endogenous" growth school can (somewhat crudely) be associated with the view that non-intervention is the appropriate policy stance since by definition all margins have been optimized and there are no "externalities" or spillovers which have not been internalized. The endogenous technological change school takes the view that observed changes in MFP reflect a host of factors including technological change. Quality change itself is an aspect of technological change. Moreover, markets for new technology are viewed as unreliable and characterized by both imperfect information and appropriability problems, all leading to a number of market failures which can potentially be corrected via appropriate policy. In this sense then the endogenous growth approach is *potentially* supportive of interventionist policies which can affect productivity growth, subject to the usual caveats about the limits of government intervention. MFP statistics are viewed as useful by the endogenous growth school but it remains cautious about correcting for quality changes, since much of what its proponents would think of as technological change is no longer counted as such.

PRODUCTIVITY DRIVERS AND LEVERS

IN THE LAST SECTION WE CONSIDERED how productivity has been measured and how the measurement debate sets part of the context in which productivity "policies" are discussed. There is a long empirical and theoretical tradition which seeks to explain what determines productivity in a causal sense. Empirically this has involved both cross-section and time-series analysis of industries and countries. Having measured productivity in some manner, other factors are brought in which are thought to explain, or *cause* productivity growth. The basic statistical model of such a study has the form of a regression analysis where productivity is on the left-hand side and various "determinants" X are on the right-hand side. Thus,

$$(1) \quad \Delta A = \beta \bullet X + \gamma Z,$$

X is a set of factors such as investment or innovation and Z is a set of policy variables, such as taxation. In Equation (1) the parameters β are thought of as productivity multipliers or "spillover parameters". Policy variables may have a direct effect on productivity or an indirect effect through their influence on X. Note that the change in productivity on the left-hand side is itself a constructed variable and therefore how one measures productivity will influence the outcome of the study in important ways. One of the most influential group of studies in this vein derive from what is known as the cross-sectional growth regression literature and is reviewed by Temple (1999). What is studied here is not productivity directly, but rates of growth of real GDP per capita for a large number of countries in the post-war period. Subject to the caveats discussed earlier about the connection between these two variables, most researchers feel that at least over long time periods the two are highly correlated. The cross-country growth evidence therefore is viewed as highly pertinent of what we know about the determinants of productivity growth.[8] The availability of this evidence has profoundly changed the way economists think about economic growth and the results have been widely supportive of the endogenous growth perspective. While growth in GDP per capita is not the same as MFP for example, a number of studies show that they are very closely related. The outcome of these studies, and of a host of other country-specific studies, has led to what I would call a consensus view on the three main correlates of national productivity growth

— let's call then the Big 3. They are, respectively, investment in machinery and equipment, human capital development, and openness to trade and investment. In the literally hundreds of studies that have been done these three variables show up as robustly and highly correlated with productivity growth or growth in per capita GDP. Let us consider each of these in turn.

PRODUCTIVITY DRIVERS: THE BIG 3

Investment in Machinery and Equipment

Productivity growth is strong and highly correlated with investment in machinery and equipment (M&E) measured as a share of GDP. Countries with high rates of investment in M&E as a share of GDP have high growth rates on average, after controlling for obvious factors such as the level of income at the beginning of the period. This latter effect corrects for what is known as conditional convergence or "catch-up" — other things being equal a poor country can be expected to grow faster than a rich country.[9] This strong correlation holds up over long historical periods and, based on more recent evidence, in both developed and developing countries. The correlation is subject to multiple interpretations. The conventional view is that M&E investment carries with it new technology and new ideas which diffuse slowly through the economy, ultimately contributing to further growth. DeLong and Summers (1991) calculate that social returns to M&E investment exceed private returns by a substantial margin. Estimates put social returns in the range of 16 to 18 percent while private returns are usually in the 6 percent range suggesting substantial spillovers (see Masden, 1998, for a review). Causality however remains a contentious issue. Some scholars point to the difficulty of showing that investment causes growth and some claim to find the opposite. A related literature on vintage effects has lent further weight to the importance of investment in economic growth. Greenwood, Hercowitz and Krusell (1997) note that the fact that the relative price of equipment has fallen steadily at the rate of approximately 4 percent a year over the last two decades is strongly suggestive that recent technological change is embodied in new machinery, or what they term *investment-specific technological change*. Using a more appropriate accounting framework than is used in conventional growth accounting, they calculate that 63 percent of U.S. output growth per worker has been due to investment-specific technological advance. Taken together this evidence is strongly supportive of the role of investment as a proximate cause of productivity growth. If one could establish reverse causality this would significantly weaken the case for economic policies targeted at investment.[10] The case for investment led economic growth has been an enduring theme of the endogenous growth literature.

Education, Training and Human Capital

The endogenous growth literature has placed a lot of importance on the role of human capital formation in the growth process, and these variables find considerable support in various growth and productivity studies. Human capital appears as an engine of growth in two ways. One, it serves to facilitate knowledge spillovers, which raises the productivity of all factors. Or in more conventional language, being more skilled makes it more likely you will transmit what you know to others, who then will do the same and so on. Two, higher skills enter directly into the production of new technology (product and process innovation), and are necessary to facilitate the adoption of new technology. In other words, a computer without software is not very useful, nor is it of much use if the workers don't know how to run it. At the aggregate level, empirical work by Barro and Lee (1994) on various proxies of human capital and growth comes to the conclusion that it figures prominently in explaining the growth performance in a broad cross-section of national economies from 1970 to 1990. Unfortunately, much of this work may not have a great deal of bearing on Canadian TFP performance as the proxies used for human capital are sufficiently crude as to leave Canada indistinguishable from a number of other advanced countries. Furthermore, much of the evidence from the cross-country growth regressions is no doubt driven by the developing country experience. Slightly more interesting is the work on MFP growth by Benahib and Spiegel (1994). They interestingly reject the conventional assumption that the level of output depends on the stock of human capital as one would expect in a conventional production function framework, but find support for the endogenous growth hypothesis that the rate of change of MFP depends on the stock of human capital. Human capital therefore increases the rate at which knowledge grows and is utilized. Furthermore, they find strong support for the view that this form of growth interacts positively with the openness variable. These results are clearly very favourable to countries such as Canada — those with a high degree of openness and a high level of human capital.

Once we go beyond the macro results things get rather murky. As is well known, the literature on training suggests that these programs don't seem to accomplish much. Learning-by-doing (LBD) has received increased support in a number of recent studies,[11] and suggests that firm-specific experience of individuals matters a lot. LBD interacts with demography because of the job experience of youth. In terms of the Canada-U.S. comparisons, human capital both helps and hinders in resolving the puzzle. As noted by Murphy, Riddell and Romer (1998) in looking at Canada versus the United States, Canada has had substantially faster growth in human capital in the 1980s as measured by educational outcomes in the two countries. The faster relative growth rate of Canadian human capital under the Benahib-Spiegel endogenous growth framework should have led to faster growth in conventionally measured Canadian MFP than in the United States.[12]

Openness to Trade and Investment

A wide range of data points to the importance for productivity growth of openness to trade and investment. This shows up in careful case study evidence as the Ben-David (1993) study of European income convergence and in cross-country data; there is a long list of studies on this point, but Sachs and Warner (1995) has been one of the more influential. The evidence now seems overwhelming although for many years there was considerable doubt as to the potential causal links between trade and growth. While the correlation is strong between openness and productivity growth there are a wide range of potential reasons for this link. Among the more important arguments suggesting why the link is so strong are the following:

- Low trade barriers facilitate better use of resources based on traditional comparative advantage arguments.
- For small countries, openness allows the realization of scale economies which are necessary in modern manufacturing and not feasible if reliance is placed on the domestic market alone.[13]
- International trade facilitates diffusion, learning and the transmission of ideas and technology from abroad. There is substantial recent evidence on the importance of international spillovers in facilitating productivity growth. This is true both internationally (Coe and Helpman, 1995) and in the Canadian case (Bernstein, 1994).
- Similar effects are fostered through foreign direct investment (FDI). Inward FDI in addition to providing capital, provides technology, skill upgrading, and market access (perhaps indirectly) and sometimes in those industries where global concentration is high (e.g. commercial aircraft, where we sell parts). Outward FDI helps in generating market access (e.g. in the United States), and securing durable links for Canadian firms with international networks, which provide high-wage jobs for Canadians, and in securing technology links in foreign countries.
- Openness implies a greater share of economic activity in exporting and there is some evidence that exporting firms tend to have higher productivity growth than do domestic or import competing firms. (Bernard and Jensen, 1999; Rao and Ahmad, 1997).

THE BROADER CONTEXT OF PRODUCTIVITY GROWTH

WHILE THERE IS OVERWHELMING EMPIRICAL SUPPORT for the Big 3 as proximate productivity drivers, there is no lack of alternative hypotheses on what determines productivity growth, especially as we move from the proximate determinants to the indirect linkages. The economic literature and the business press are virtually awash in explanations as to what drives productivity growth. This should not be a surprise since the basic question — the source of the wealth of nations — remains one of the most contentious and frequently debated issues of the day. In order to draw some boundaries around the debate let me mention some of the explanations that have had some relevance in the recent Canadian context:

- innovation (both product and process);
- diffusion of technology (national and international);
- spatial agglomeration (Silicon Valley);
- external economies of scale at industry level;
- government consumption (negative);
- management practices;
- public infrastructure (positive);
- income inequality (negative);
- high taxes (negative);
- small firms (negative);
- labour market flexibility (positive);
- exchange rate stability (positive);
- low inflation (positive).

One can find studies which suggest the link of one of more of these variables to productivity or growth in GDP per capita, and in many cases there is some supportive evidence of correlation. There are of course a number of problems: (1) Causality is not the same as correlation and most of these variables are in fact endogenous; (2) in many instances, the time period examined is limited or the sample size is small; (3) economic theory is usually ambiguous as to the predicted effect on productivity. On almost all of these the evidence remains controversial. Moreover, the lags between the initial application of any lever and ultimate productivity effects are very long and highly uncertain due to inherent uncertainty in the transmission process. Finally, the feedback effects running between and from these various factors are potentially enormous, complicating the ability of any study to identify the causal pathways. Nevertheless, some of these are likely to be more important than others in the productivity debates of the 21st century. In the interest of adding to this debate, I want to focus my remarks on four factors which are likely to figure prominently in future productivity debates in Canada.

Innovation and Technology Diffusion

Most of the endogenous growth literature identifies knowledge spillovers as the ultimate engine of growth. As Paul Romer has emphasized, ideas are not subject to the law of diminishing returns. As knowledge accumulates this knowledge is potentially available for all to use at very low cost, and can lead to a self-reinforcing endogenous growth process. However, ideas in the form of useful technology are created by individuals, firms and governments in a highly imperfect process. There is a long tradition in Canadian industrial policy to focus on concerns about the weakness of the innovative process in Canada. These concerns are shared in virtually every smaller open industrialized economy that I am aware of, and come naturally when (a) most of your markets for new products are external, (b) a large share of the world's knowledge is generated outside your own borders, and (c) foreign-owned multinationals have a large presence in the domestic economy. I will not review the large Canadian policy literature on this issue except to note that recent productivity numbers suggest Canada does quite well at process innovation but tends to lag in product innovation.[14] International diffusion of technology either via spillover, or via explicit technology adoption figures prominently in any likely explanation of productivity change in Canada. On the technology adoption front, the evidence for Canada is mixed. Baldwin and Sabourin (1998) find that the major disadvantage Canadian plants face in technological adoption relative to the United States is the smaller market size, with some additional worries about labour market inflexibility. Beyond that, barriers to technological adoption in the two countries appear to be similar.

Innovations result in the most part from deliberate and costly attempts to develop new technologies or products. There are two important debates here: (a) What are the private and social returns to innovation? and (b) To what extent is the innovation process subject to market failures or "spillovers?" Productivity and innovation are uniquely related in a number of ways. Some measures of MFP attempt to internalize the inputs to innovation by measuring resources devoted to R&D as inputs and isolating the MFP changes after costing out R&D inputs. Within this framework, some of the returns to innovation are ultimately captured by the innovator, just as in the case of any other form of investment. Critics argue that the static production function framework fails to capture the inherently risky and non-appropriable nature of knowledge creation.

Going beyond this approach in a lot of recent empirical work, the effect of R&D expenditures on productivity is measured as the changes in private sector MFP attributable to the "spillovers" from collective R&D, both domestic and foreign, but not captured by the R&D inputs directly. Coe and Helpman (1995) set off a new line of research when they linked the strength of international R&D spillovers on national MFP growth to trade patterns. The international non-appropriable transfer of knowledge in economies more open to international trade and investment has been one hypothesis suggested by numerous scholars. The Coe-Helpman research distinguished between domestic R&D, global R&D and the facilitating role of trade. For Canada, their results indicate that global R&D is more important than domestic R&D and that this variable interacts with trade, measured by the import share, in facilitating knowledge transfers. To give an example, Bayoumi, Coe and Helpman (1995) estimate the cumulative effect of permanently increasing the share of GDP devoted to R&D by 0.5 percent in selected countries and looking at the macroeconomic effects over a 75-year period. In the case of the United States, for example, this would amount to about a 25 percent increase in R&D spending. Their simulations show this would produce a 9 percent increase in U.S. potential output and a 6.8 percent increase in Canadian output. Jeff Bernstein looking at Canada-U.S. spillovers comes to similar conclusions. The results suggest that Canada is a major beneficiary of U.S. and global innovation spillovers, although the dynamics of this process are uncertain.

In contrast to the spillovers approach, many economists view R&D and the innovations it leads to as fully "bought and paid for." Thus, the market is assumed to correctly price innovation inputs and outputs with no identifiable market failure. The policy implications of the two alternative approaches to innovation are very important and have played a long-standing role within the Canadian debate about R&D policy. Economists still argue at great length about how innovation shows up in the economy.[15] There are a number of potential channels — lower prices, higher factor returns, greater output growth, or higher profits. In a closed economy, where production must equal consumption, with some caveats the exact channel will not matter at the aggregate level. But where innovation impacts on consumers versus producers versus workers matters a great deal in an open economy for the ultimate impact on living standards.

Many people, myself included, put substantial weight on the Schumpeterian view that innovation occurs in imperfectly competitive industries, and that over medium-term horizons the rents from innovation are an important driving force for entrepreneurial activity. Furthermore, this process is characterized by substantial risk to the individual innovator. Schumpeter argued that a successful innovation causes "creative destruction" which not only results in new goods with high economic value, but at the same time destroy value in old goods or industries through obsolescence. If this is an accurate description of how technological change occurs then some interesting implications follow. First, policies which affect private sector innovation, and in particular policies toward new firms and entrepreneurs, become potentially important "productivity levers." Second, measured ex-post productivity growth in Schumpeterian industries can be biased downward due to the inappropriate measurement of inputs by counting obsolesced resources. Third, one has to be careful drawing a close link between high rates of innovation and socially optimal policies. It is quite possible that private markets can actually overinvest in innovation relative to the socially correct level due to the "destruction effect" of innovation. The cost-benefit calculation is further complicated by the fact that innovation rents which result from holding price above marginal cost do not constitute a national efficiency loss if the majority of consumers are foreigners. The consumer loss in other countries constitutes a gain to producers and workers in the country which has a temporary monopoly by reason of a Schumpeterian innovation success. Microsoft's monopoly may not benefit American consumers but it has certainly benefited Microsoft employees and shareholders.

Scale, Urbanization and Agglomeration

There are a number of economic theories which emphasize the (Marshallian) observation that the greater the scale of an activity through the agglomeration of like activities in a particular region (Silicon Valley) or city the higher are productivity levels in that activity or sector. Most of these theories emphasize the mobility of firms across space, but others focus on mobility of people as well. The exact source of these productivity gains remains a subject of considerable controversy: dynamic knowledge spillovers, ease of communication, facilitation of learning, and so forth. Much of the literature is focused on the apparent correlation between economic growth and the growth of cities. Localization economies and informational externalities are thought to be important reasons for the agglomeration of economic activity within cities. The recent literature contains a number of interesting facts that bear directly on the growth process in Canada. Here are some of the more interesting ones.[16]

1. There is growing consensus on the existence of strong economies due to agglomeration, at least in manufacturing. Agglomeration can be either at the city level or at the regional level. (Ellison and Glaeser, 1997).
2. From 1900 to 1950, the average metropolitan area population tripled and the number of metro areas doubled in the United States. Despite growth in individual city size in every decade the "number" of cities also increased — urbanized population rose from 40 to 60 percent. Note at the same time the large increase in average human capital as evidenced by school completion rates. (Black and Henderson, 1997).
3. Cities are either economically specialized into financial services, business services or manufacturing — with significant differences in education

levels associated with these city types — or they are diversified. Diversified cities tend to be larger than specialized cities.

4. There is evidence that city growth rates are strongly related to growth rates in human capital within cities. (Black and Henderson, 1999).
5. Diversity within cities and local competition tend to foster urban employment growth while specialization appears to reduce growth (thus diversity may be important for attracting new and growing sectors).
6. Diversity also tends to promote innovation. Feldman and Audretsch (1999) find in a data set involving U.S. product innovations in 1982 that 96 percent were created in metropolitan areas that account for only 30 percent of the U.S. population.
7. Specialized cities have some advantages — stronger localization economies within the sector of specialization and thus the ability to attract new plants and firms entering that type of activity, but they also have disadvantages — less innovation and greater exposure to risk as the specific sectors and technologies rise and fall.

Most of these facts derive from U.S. and European studies but they carry implications for Canada. Canada is also highly urbanized with only four major cities that might be thought of as diversified. Given the importance of city growth to the overall growth process, it seems odd that most accounts of Canadian productivity performance make little mention of the role of cities. Some of this analysis has been extended to regions and, of course, there is a long Canadian concern with regional inequalities and its effect on growth (Coulombe, 1997). The manner in which city growth contributes to overall growth in Canada needs further research.

General Purpose Technologies

A new paradigm of historical technological change is that much of what we observe is associated with large scale shifts in the entire technological system: the introduction of steam and railways in the 19th century, electrification early in the 20th century and later Fordism or mass production methods. The concept of a *general purpose technology* refers to a major innovation which has widespread uses within the economy and whose introduction in turn leads to wholesale transformation of production and distribution systems with attendant innovation. This topic has been explored intensively at the Canadian Institute for Advanced Research, and the recent volume edited by Elhanan Helpman (1998) covers the topic in detail. The introduction of GPTs is characterized by long lags between the date of introduction and ultimate productivity gains. There is also considerable initial uncertainty as to the ultimate effect of a new GPT. Growth based on a new GPT is to be contrasted with technological innovation which is thought to be continuous and incremental in nature. The information technology revolution based on computerization and low-cost electronic networks surely constitute a classic GPT. From a measurement perspective, a GPT is a nightmare. The basic difficulty stems from the long lags which occur between the original emergence of the innovation and its ultimate usefulness in the economy due to a host of problems. People need to learn about the technology, there are extensive networks and facilitating infrastructures that need to be created, and many uses of the technology only become apparent long after it has first appeared. Furthermore, the economy goes through a substantial adjustment period in which the old technology is slowly discarded. Measured MFP will almost certainly tend to fall during this period both because output growth slows initially, and because inputs are actually made obsolescent by the shift, but are still measured. Economic growth is thus characterized by waves of slow to negative measured growth, perhaps lasting as long as two decades, followed by increasingly rapid growth in productivity. The productivity slowdown of the 70s and 80s might be attributed to the emergence of this new GPT and the recent pickup in productivity is likewise explainable by the payoff of this technology finally becoming evident in the data.

The GPT concept parallels closely the "new economy" debate which will be addressed in the next section. If a lot of productivity change is due to a maturing GPT a number of issues follow. First, in order to justify policy interventions one needs to know the precise manner in which a GPT is likely to affect future economic development, and in particular the best form of the facilitating innovation and infrastructure. As governments do not have perfect foresight, this is not easy to do. Nevertheless governments can help to coordinate market expectations as to the likely course of a GPT, and secondly provide the appropriate public infrastructure that is often necessary for a GPT to reach its full potential.

Productivity Dynamics and Microeconomic Heterogeneity

Measured productivity growth of almost any economic aggregate, be it an industry a region or a country, reflects two things going on at the microeconomic level of the many individual sectors/activities/firms which make up the aggregate. The aggregate rate of productivity growth can reflect either a pattern or relatively uniform productivity change within the respective micro units, or alternatively it can reflect a reallocation of resources across micro units with substantial heterogeneity in both levels and rates of productivity growth. There is a growing body of evidence that the growth process is fundamentally driven by the *reallocation of resources from low-productivity growth activities to high-productivity growth activities, rather than by limits on the availability of new technology.*

The principal data behind this observation is the incredible heterogeneity which microeconomic productivity statistics has revealed in a large number of studies in recent years. Looking across firms within an industry, or across industries within a country, or at industries across countries, we observe remarkable heterogeneity in measured productivity levels and growth rates. It is quite common to find plant productivity levels which differ by a factor of two to three in a narrowly defined industry and time period. Furthermore, there is a remarkable persistence in the lack of convergence of productivity levels within industries. Important studies which have contributed to this view include Baily et al. (1992), Baldwin (1996), and Dwyer (1995), and new ones have been appearing with increasing frequency. At the national level, this appears to have shown up in a reversal of convergence trends in productivity levels in manufacturing across countries beginning about the mid-80s (Bernard and Jones, 1996). In this case, heterogeneity has extended to the international level.

An important research question is why this heterogeneity persists. One explanation is simply that the data reflect vintage effects — older firms tend to use older technology and thus are less productive or further from best practice. Other explanations hinge on the observation that productivity can be dependent upon firm-specific assets, such as location or the skills of management, which are not replicable. It turns out that the latter story seems to be more important at least in some studies.[17] Productivity growth appears to be an aggregation phenomena. New plants tend to have significant and relatively permanent higher productivity levels. Output growth within an industry occurs due to entry, exit and output growth or contraction at the level of the individual plant. Output growth and contraction appears to play a dominant role in explaining productivity growth. Productivity growth is observed as more productive plants expand and less productive plants contract.

There are a number of implications that can be drawn from the widespread evidence on extensive heterogeneity in productivity levels. One, the resource allocation process is far from perfect in that similar resources have differential returns (rewards) in different activities. Observed economic growth is due in substantial part to the re-allocation of resources from low-value uses to high-value uses. The productivity effect of any policy will thus depend in part on the way in which it either retards or promotes the re-allocation of resources from low to high value uses. Second, the potential economic gains from these re-allocations are likely to be larger during periods of rapid technological progress. This occurs since rapid technological progress has also been associated with greater dispersion in observed micro productivity levels. The greater the dispersion the larger the benefit in moving resources from low-productivity plants to high-productivity plants.

Macro Factors: Unemployment, Aggregate Demand and the Exchange Rate

Most of the debate on changes in productivity is motivated by either secular changes in measured growth rates, or by persistent differences in living standards which go beyond the time period associated with a business cycle. Nevertheless, there is a long tradition in economics of identifying weak aggregate demand as a potential cause of productivity change. As is well known and argued forcefully by Pierre Fortin (1994, 1996), output growth in Canada in the 1990s has been unusually weak. Fortin attributes this weakness to macroeconomic factors on the aggregate demand side. If there is a causation running from aggregate demand to long-term productivity growth this has the potential to be an important factor in both explaining and resolving some of the productivity problems in Canada. Virtually all economists would accept the proposition that there are medium-term links between productivity and output growth; however, there is substantial disagreement as to whether long-term productivity trends can be affected by economic stabilization policy — either fiscal or monetary.

In the literature, there are three separate potential linkages running from aggregate demand to productivity growth:

1. Some theories suggest that weak aggregate demand reduces output growth for a given labour force. Low output growth tends to reduce productivity growth directly via negative dynamic learning-by-doing effects or the existence of dynamic scale economies. Firms which are not expanding are not learning and this reduces productivity. This is sometimes referred to as the "Verdooun effect."

2. Other theories suggest that the temporary reduction in aggregate demand has lasting long-term negative effects on unemployment. Over a period of a few years, a high rate of unemployment can induce hysteretic negative productivity effects on the labour force through de-skilling — i.e. being out of work for a long period causes a loss of skill which in turn leads to lower future productivity.

3. Finally, there is what might be termed the "heterodox view" associated with the Austrian school that recessions are a good thing. The "cleansing recession" hypothesis is that cyclical downturns facilitate the obsolescence of old technology and the re-allocation of resources to new, more highly productive uses. In essence, recessions are manifestations of "creative destruction."

If one takes the Keynesian view that economies will tend not to revert naturally to a long-run full-employment equilibrium, then the first two theories would both suggest that sustained periods of weak output growth can reduce productivity over the longer run. Furthermore, supply-side oriented policies which may otherwise enhance productivity are doomed to failure unless aggregate demand is sufficiently buoyant. It is interesting to note that the Europe-U.S. comparisons have not been brought up more often in the Canadian productivity debate. Europe has high unemployment and high productivity growth relative to the United States, although Europe also had a productivity slowdown. The standard explanation for this difference is that rigid labour markets in Europe have induced firms to substitute capital for labour leading to both job losses, but increased productivity. This is sometimes characterized as the "OECD hypothesis" and has received a lot of attention by Canadian labour economists, most recently Craig Riddell (1999). However, the same evidence casts doubt on whether weak output growth or high unemployment necessarily has long-term effects on productivity given the strong European productivity record. However, the recent pick-up in both output growth and productivity growth in the United States is likely to re-new this debate.

A related macroeconomic productivity link is the exchange rate. Recently there has been considerable debate on whether the trend depreciation in the Canadian dollar could have contributed to the low levels of productivity observed in Canadian manufacturing relative to the United States. This hypothesis is discussed at length by Tom Courchene and myself (Courchene and Harris, 1999) and is an important part of the debate on the costs and benefits of a North American Monetary Union. A number of commentators have pointed out that short-term measures of cost competitiveness between Canada and the United States have been favourable to Canada largely due to the lower Canadian dollar. Canadian productivity levels in manufacturing are still below those of the United States. Of the various arguments that would suggest a causation running from the exchange rate to productivity the simplest is that domestic firms faced with a depreciating currency simply could avoid making necessary productivity improvements in order to remain internationally competitive. A more complicated argument involves the simultaneous interaction between a depreciating currency during a period of rapid product innovation in the United States. A cheap dollar has the effect of encouraging Canadian firms to expand in areas where cost competitiveness was most valuable, and to avoid making investments in product-based R&D, the cost of which had risen due to the use of new technology and skilled labour inputs priced in U.S. dollars. Both these explanations await further research. The more conventional macroeconomic theory is that lower trend productivity growth in tradable manufacturing sectors relative to one's trading partners "causes" a depreciating real exchange rate, rather than having the exchange rate depreciation cause lower productivity growth. But it is also true that the evidence on the traditional linkage is quite weak.[18]

PRODUCTIVITY GROWTH IN THE 21ST CENTURY

ASSESSING THE HISTORICAL RECORD ON PRODUCTIVITY is an area subject to considerable dispute. It is obvious but no less important to note that productivity trends in Canada are likely to mirror closely those of the global economy. The recent pickup in productivity numbers, particularly in the United States, has raised considerably expectations that these trends will start to emerge elsewhere. One should be cautious however to extrapolate recent trends either through time or across countries. Over the economic cycle, there is enormous volatility in measured labour productivity growth. Business cycles vary in length from 5 to 36 quarters in the post-war period — the current one is of course particularly long. In recoveries, productivity growth varies between 0 and plus 6 percent with weak persistence. Looking across countries, there are two striking features in the data. First, a large variation across countries in growth rates, and secondly over longer periods remarkably little long term persistence in growth rates between periods. In the 125-country Summer-Hestons data set, growth rates in the last 25 years have ranged from over 5 percent to negative. In terms of persistence, the correlation between 1962-72 growth rates and 1975-83 growth rates is only 0.16.[19] The implication of this is that individual country experience probably cannot be extrapolated either to other countries or into the future with any great degree of certainty. The good news however is that a poor growth performance in the past is not a sentence for life. Good policy and good luck are always possible.

Despite the problems inherent in "productivity speculation," vision requires a forward looking view. What might turn out to be the important trends that matter for Canadian productivity growth in the next few decades? My remarks will focus on three key developments:

- demography;
- globalization and North American economic integration; and
- the "new economy" debate.

THE DEMOGRAPHIC CHALLENGE

IT IS CLEAR that one of the most important future developments with strong productivity implications is demographic trends in Canada, and indeed in most western industrial countries. Most demographic experts agree on the following:[20]

- Over the next four decades, the median age of the labour force will increase from about 35 to 45, whereas only 30 years ago the median age was 25.
- The share of the population over 65 will be more than double by 2030.

- After 2011, there will be substantial slowing in labour force growth; holding immigration trends constant, the rate of growth in the labour force will be well below that of the population with a levelling off in the increase in female participation rates and the entry of smaller youth cohorts.

If recent productivity trends persist, these developments are problematic to say the least — for both public policy and economic growth. Most forecasters note that since the government tends to spend about three dollars on the elderly for every dollar spent on youth there will be a dramatic rise in the expenditure dependency ratio — i.e. spending on dependents as a share of GDP. The only hope for an offset to this in the absence of policy changes would be a dramatic increase in labour productivity growth. Most estimate that if labour productivity growth were to move into the 2 percent range current expenditure programs could be maintained without a substantial increase in budget deficits.[21] What is the likelihood of such a trend increase in productivity growth? Perhaps not impossible as we shall see. However, the aging population carries with it another implication. As workers age, particularly after the mid 40s, existing studies by labour economists show that their productivity tends to decline. The major evidence for this is found in cohort-wage studies. The substantial increase in the median age of the labour force should therefore also be associated with a decrease in the average productivity level of the labour force. Simply put, a labour force full of 55-60 year-olds will produce a lot less than a labour force full of 40-45 year-olds. Therefore, we are in a double bind; not only are expenditures linked to increased dependency likely to rise, but the average productivity of those who will be working is likely to decline.

Are there any outs to this otherwise rather pessimistic scenario? Well, there are at least four possible developments that might at least reduce the tension:

1. Machine-muscle substitution. The history of technological change has been a series of innovations which have substituted machine movements for muscles. Robots on the floor of manufacturing plants are only one example. Since loss of muscle strength and agility is a major feature of the aging process, additional innovation which results in the substitution of machines for muscles is likely to continue to be an important feature of future technological change. Examples abound and are found increasingly in service industries as well as in manufacturing. Automatic food serving vendors, better baggage handling technology, and so forth.

2. Machine-neuron complementarity. The modern Luddite worries that smart machines will eliminate the need for human intelligence

— the substitution of chips for neurons. While in some cases there is of course one-to-one replacement of a person by a machine (the ATM for example), much of modern technology built around the computer is to aid human intelligence — that is, it is complementary to human intelligence. Additional innovation with respect to this type of technology is likely to help an aging labour force retain its productivity. Two areas which come to mind are of particular importance with respect to aging. Technology to facilitate memory intensive tasks, and technology to facilitate learning new technology. In much the same way that rising wages induced machine-muscle innovations in the industrial era, we can reasonably expect that as the labour force ages there will be strong economic incentives to develop neuron-machine complementary innovations.

3. Medical innovation. One area where there appears to be virtually no slowing in innovations is medical science. Many developments relate directly to lengthening the ability of aging human bodies to continue to function effectively beyond what would be considered the normal retirement period. Hip replacement, laser eye surgery, etc.

4. The other side of the demographic productivity trap is the assumption that older workers will continue to retire at the same age, thus reducing output and growth, or even worse that the trend toward earlier retirement will accelerate. There are some reasons to think that this trend may reverse.[22] Not the least are a number of policy changes that could reduce the average retirement age as discussed in the recent OECD Report *Maintaining Prosperity in an Ageing Society*. The productive effects of these could be to actually increase average productivity levels in the labour force, relative to the alternatives, if the skills and experience of workers that are now retiring could be leveraged into a few more years of useful work. This is undoubtedly one of the major challenges Canada will face early in the 21st century.

Globalization Arguments

Globalization is an inexorable trend that has been with us for a very long time, but it appears to have accelerated in the 1980s. Globalization has a number of important productivity implications for Canada both on the positive and on the negative side. Three aspects of globalization warrant attention with regard to Canadian productivity prospects. The potential slowdown in the growth of world trade and foreign investment, the agglomeration trends within an integrated North American market, and the emergence of a global market for the very highly skilled.

A Potential Slowdown in the Growth of the Global Economy

Chad Jones of Stanford University recently wrote a paper with the provocative title *The Coming Productivity Slowdown*.[23] The thesis of the paper is actually quite simple. He argues that some of the most robust findings of the modern empirical growth literature is the close correlation between economic growth and R&D spending, the level of human capital formation, and openness to trade and investment. In the case of human capital he notes that, in 1940, less than 1 in 20 in the labour force had completed high school. By 1990, 80 percent had completed high school and more than 20 percent had some form of higher education. Over the same period, the United States had opened up substantially to trade and international investment with close to a tripling of the openness ratio. Finally, the number of scientists and engineers engaged in R&D in the United States increased from 0.25 percent of the labour force in 1950 to 0.75 percent of the labour force in 1990. He then argues that all of these trends are now slowing but the rapid increase in these variables over the last four decades has been responsible for much of the high growth observed during the same period.

The case that all these trends might slow significantly is clearly speculative. World trade has been growing steadily at about 8 percent per year — well above world GDP growth. How long can this go on? It is not difficult to take the view that the growth in international trade witnessed in the last two decades is bound to slow for a number of reasons. Not the least is the simple observation that as the share of services in the economy gets very large, trade in goods becomes less significant. Thus, growth in trade volumes expressed as a percentage of GDP will eventually level off. Jones argues that U.S. growth has been driven in large part by an increase in trade, and as that growth levels off so will productivity growth. Investment in innovation seems also to be slowing down as witnessed by the number of scientists and engineers who are engaged in R&D. Finally, the rapid increase in U.S. rates of participation in higher education is another trend that appears to have slowed. He then argues that if ones takes the empirical growth literature seriously the implications for future U.S. productivity growth are dismal to put it mildly. Using a fairly standard growth model he calculates that *the rate of growth per capita GDP in the United States will fall to one quarter of its average post-war level early in the 21st century*.

Is any of this to be taken seriously? While the paper was meant to be provocative, what he points out is certainly worth contemplating. First, the trends that he discusses are evident in most countries and have certainly been good for growth. Admittedly, it seems difficult to believe that these trends can persist indefinitely. Canada has benefited enormously from increased openness since the FTA/NAFTA, with international exports growing from about 25 percent of GDP to more than 40 percent. If that was positive for growth then as that export growth slows so will productivity growth, even if the level effects remain. Moreover, if growth in the United States slows, given the large extent to which Canada relies on technology spillovers from the United States any potential slowdown there will have strong negative implications for Canadian economic growth, as the Helpman-Coe/Bernstein spillover results suggest. On a more positive note, however, it may be that growth in openness of the Canadian economy is far from over. Other small open economies in Europe such as Belgium, the Netherlands and Austria have much higher openness ratios than Canada — in some cases close to 100 percent. If their experience is indicative of where Canada is headed we may enjoy a productivity growth dividend for a number of decades as the economy evolves in that direction. This presumes of course that things "work out" in our neighbour to the South. If Jones is correct and the United States heads into a protracted productivity slowdown, things are worse than we imagine.

North American Integration and Regional Agglomeration

In Europe, the emerging literature on trade and geography has renewed worries about regional growth poles, and center-periphery asymmetric development within the European Union as firms become increasingly mobile within a more fully integrated economic area. All of these same issues are beginning to be discussed here as an integrated North American economy emerges. Will some or all of Canada's regions become regional backwaters as the forces of agglomeration push high value-added activity into U.S. based growth poles? On theoretical grounds all of this is possible of course. One has to genuinely worry that agglomeration is such a powerful force that it may relegate Canada to a collection of locations that are highly specialized, but less involved in innovative and high value-added activities. The importance of cities, for example, suggests that Canada has to have a sufficient number of highly diversified and human capital intensive cities if it is to maintain high rates of productivity growth. As Courchene and Telmer (1998) argue, if Canada is integrating North-South it may well be that in the 21st century growth prospects will be region-specific with the growth of each Canadian region mirroring that of the respective region to the South. National economic policy might counteract such tendencies but given the close links between these regions it is hard to imagine how national policy could reverse a Canadian region's decline if the adjacent U.S. region were to go into a protracted growth slump.

These regional worries have international analogues — agglomeration effects which appear to be biased against small countries — small countries will be de-industrialized, will have no world-class cities, and no major Silicon valleys, etc. By this set of arguments "smallness" in itself guarantees low productivity levels. Fortunately, I think these arguments are limited and the negative effects can be avoided by appropriate integration or exploitation of global markets.[24] Examples abound of small countries that have very high levels of productivity and income — Switzerland, Finland, Singapore, and the Netherlands, for example. Furthermore, there is virtually no evidence that growth is related to country size. On the available case-study and econometric evidence, there appears to be no a priori justification for the idea that Canada will be "hollowed" out by a more integrated North American market.

Nevertheless, it is very important to understand how the factors which lead to agglomeration — localization economies, learning-by-doing, and knowledge spillovers — work in detail so that appropriate strategic and compensating policies can be put in place. One simple example: if low corporate tax rates are a necessary condition for a small country to attract FDI away from larger economic areas because of the presence of agglomeration effects, then being competitive on tax rates internationally for mobile economic activities will be essential to economic growth.[25]

The Global Market for Human Capital

AS MORE ECONOMIC ACTIVITY is based on human capital advantages the skill mix of the labour force becomes an important long-term determinant of an economy's industrial structure, and changes in the level of investment in human capital will tend to have greater impact on economic growth than it may have had in the past. Many "high tech" activities are inherently footloose (unlike agriculture or resource industries) — people are the only "sticky factor." The people that "make or break" a firm however are the very highly skilled employees and managers; globalization has raised substantially the real wages of those who have acquired critical skills. The skills shortage in the IT sector is a good example. As noted previously, Canada has a strong record on human capital formation, but that may not be enough. The fear of many is that the labour market for these people has become truly global, raising the prospect of a new class of worker — the global "gold collar" worker who can work in any country and has little national allegiance as it was typically ascribed to the labour force in the past.

An emerging global market for highly skilled workers will affect Canadian productivity growth in obvious ways. First, these workers are necessary for the transfer of best-practice international technology to facilitate learning new technologies and to foster Canadian based innovation. Second, human capital is complementary to a lot of physical capital — hence in the global competition for new investment, the ability to attract and keep highly skilled human capital will be a necessary condition for growth. An opposing view is that the global market for human capital is relatively insignificant — after all, most workers never leave their home region, let alone their country, and rates of international migration are still relatively low.[26] As the media debate on the "brain drain" indicates, both sides can point to supporting evidence, and so the arguments will go on for some time. If the global "gold collar" labour market proponents are correct, and this trend accelerates, it will impact on all countries in a wide range of ways. The potential productivity implications are however enormous and at this point unquantifiable. Yet, a third perspective would be that of an extreme "neoclassical optimist" who would argue that mobility of workers, skilled or unskilled, is always a good thing. Increased mobility raises world income, and with the rapid diffusion of ideas the geographic location of a particular "brain" is of little consequence. I would like to believe this, but the evidence on agglomeration in growth patterns suggests it is too sanguine a view. There may be thresholds on skilled labour supply below which the viability of an industry in a particular region becomes tenuous.

THE "NEW ECONOMY" DEBATE

PROMISES OF A NEW "GOLDEN AGE" of high but possibly unmeasured productivity growth fills the pages of newspapers daily, and has gathered considerable recent support by such notables as Alan Greenspan. The recent evidence is certainly impressive in the case of the U.S. economy. Average labour productivity grew at an annualized rate of 2.15 percent from 1995 through the first quarter of 1999, after growing at just over 1 percent from 1972 to 1995. Does this herald the return to the golden age of productivity growth witnessed in the 1950 to 1970 period, in which productivity grew at a rate in excess of 2.5 percent? If so the impact would be remarkable both on the real incomes of workers and on the ability of government to fund program spending. There are doubters, however, and their arguments are impressive. Robert Gordon (1999) of Northwestern University notes that the entire pickup is predicated on one remarkable fact — the significant drop in computer prices over the last few years.[27] Growth in computer manufacturing proceeded at an astounding rate of 42 percent over the 1995Q4-1999Q1 period. This sector alone managed to raise the aggregate growth rate even though computer manufacturing accounts for just 1.2 percent of total output in the United States. Productivity growth in non-computer manufacturing (durables and non durables) actually declined during 1995-99 relative to 1972-95. Gordon therefore argues the New Economy simply isn't a statistical reality and, furthermore, the much talked about productivity slowdown is still very much with us. As he describes it, the computer revolution thus far has only been productivity enhancing to the extent that it has resulted in more efficient production of computers. The broader based benefits of computers and related IT are still not in the data.

It is not clear where all this leads. The Gordon position is countered in two ways. First, there are the traditional Griliches concerns with unmeasured output gains in the service sectors. True enough, but these adjustments, if made appropriately, would go back a long way and provide no evidence that there has been a recent pickup in productivity growth. On the other hand, there is some recent work using stock market data to infer productivity gains which is much more optimistic. Greenwood and Jovanovic (1999) suggests the "new economy" is real and use as evidence the stock market values of technology intensive companies, most of whom are firms that did not even exist prior to 1972. But is the stock market valuation of technology companies to be believed? Certainly, in fully rational perfect-foresight stock markets we would expect stock prices to reflect future growth in earnings, which in turn reflect productivity growth. However, "bubble theorists" are not impressed, and until productivity shows up in conventional statistics they will remain unconvinced. Of course, if computers and IT technology are a genuine GPT in the Lipsey-Helpman sense then perhaps we will simply have to wait, given the lags inherent in the evolution of a new GPT. If the "new economy" turns out not to have arrived then the 21st century will bring more of what we have had in the past, although worries about Canada falling behind the United States are likely to be less compelling.

At this point, however, there is no reason to discount completely the optimists. The anecdotal evidence is certainly impressive, and the implications for Canadian productivity growth of the "new economy" hypothesis are obviously considerable. If true, then the current period is one in which the United States can be characterized as "forging ahead," yet again.[28] If history repeats itself, Canada should start to benefit from "catch-up" effects and with appropriate facilitating policies can encourage a similar structural shift in the economy. Major policy issues will emerge as to what these policies might be — Internet infrastructure subsidies, more resources devoted to providing IT training, favourable tax treatment of IT intensive sectors, and so forth.

There is the broader question of whether the Internet and related technology will turn out to be the most important of these new technologies because of their impact on reducing the cost of distance in economic interactions. Canada is a country which has been shaped by geography. As the population becomes increasingly urbanized it can be described as an economy with a few major cities in which most GDP is produced with vast distances between them. The Internet could change that in the 21st century in ways that are hard to imagine.[29] For example, growth in medium-size cities has been hampered by the inability to overcome the benefits that agglomeration confers via localization economies on the incumbent large cities. Closely related electronic networks may substitute for physical proximity, and spillovers may arise from virtual linkages rather than geographical/physical linkages. Optimistically this might encourage growth of firms in a number of medium-size Canadian cities which are attractive living locations. In a sense this is a zero-sum activity since this activity would have to be attracted from the larger cities, but it could be productivity-improving in two ways. First, many of these spillovers might be international in scope. Firms in smaller cities could benefit from participating in virtually linked North American networks. The Internet allows firms to manage customers and suppliers in ways that hitherto were not feasible. Second, at some point large cities become inefficient as congestion rises. Transferring activity to less congested smaller cities would be efficiency-enhancing overall. Third, virtual economic integration within Canada could be expected to pickup. While Canada has a tradition of a relatively integrated common market, the fact is that interprovincial trade has fallen — interprovincial trade is now less than 20 percent of GDP whereas only a decade ago it was over 25 percent.[30] Full integration of the Canadian common market has been hindered for decades by the cost of distance. As the Internet reduces these costs, there is now the possibility of achieving the larger potential of the virtually integrated Canadian common market which comes with greater scale economies and the dynamic effects of increased competition.

Conclusion: The Policy Framework

Developing economic policies that can increase the chances that Canada will improve its productivity record are at the top of both the private and public agendas these days. There remains considerable disagreement on exactly how this is to be achieved. Part of the disagreement is genuinely ideological in nature, but a lot emanates from the ambiguity in the statistical and historical productivity records. Broadly speaking, we have some agreement on how productivity should be measured, but we recognize the problems inherent in these efforts. Also, there is a broad consensus on the fact that productivity growth declined in the mid 1970s but still disagreement as to why. Looking at the broader record we recognize that trade, investment and human capital formation are the main drivers of productivity growth, within an overall framework where knowledge creation produces opportunities for growth. Within these parameters, there remains considerable debate on what levers should be pulled to produce higher productivity growth.

A good example of this is public policy toward innovation. Here we have tension between those who view innovative activity as leading mostly to knowledge spillovers that are non-appropriable, and those who view innovation as the outcome of a Schumpeterian competition with imperfect product and factor markets. The "spillovers" school of thought is equated with market failure and its corollary, government intervention. If you are of this persuasion you seek confirmation of your views that knowledge creation is non-appropriable and governments can effectively identify the point of social-private discrepancy with limited parameter uncertainty. Alternatively, if productivity growth is due to innovations by risk-taking firms and entrepreneurs seeking temporary monopoly rents, successful innovation results in ex-post monopoly and destruction of rents on competing products and processes. Good policy in this case is focused on fostering the development of new entrepreneurs, ensuring that a temporary monopoly does not become permanent, and helping those who lose in the process of creative destruction find new jobs. However, between these perspectives, there are a wide range of alternatives corresponding to a range of theories on how the innovation process works. There is genuine unresolvable uncertainty as to which view of the world is appropriate.

The debate on "productivity levers" is subject, at almost every turn, to this type of "model" or what we call *Knightian uncertainty*. This is uncertainty that cannot be expressed in terms of a simple statistical probability, but refers to the unresolvable fact that the true causal economic pathways from policy to outcomes are unknown and may be unknowable within the time frame that is relevant to policymakers. Does encouraging investment in pulp mills, bridges or computer programmers lead to higher future growth? Is it done by lowering taxes or increasing subsidies? A useful question but what is the answer? Given Knightian uncertainty as to past causal linkages from policy to productivity, and also the considerable uncertainty with respect to the developments of the 21st century how can we think about policy choice? Here are some suggestions for the prudent Canadian policymaker:

- Be cautious: Stick to policies that are known to be, on balance, favourable towards promoting the "Big 3," and worry about policies that claim to address another problem but may cost the economy in terms of increased investment, trade or human capital formation.

- Pay attention to new evidence: In the presence of severe model uncertainty you may wish to display increased sensitivity to new and unusual information — remember anecdotes are preliminary data. I think a good example of this type of issue is the current "brain drain" debate. The traditional evidence and theory suggest that the flows of skilled workers relative to their stocks are insignificant and suggest there is little to worry about. But recent losses of "very highly skilled" workers have sent out alarm signals in the business community. It may be that the business community has an incompletely articulated model of the importance of highly skilled labour that the older theories do not represent, but that may be more relevant to the success of Canadian firms, and thus the Canadian economy.

- Be a global realist: Policies directed at productivity must be considered in light of a realistic view of the international allocation of mobile and footloose resources, and Canada's relative position in the global economy. Without a competitive policy environment for new mobile investment and highly skilled people all other productivity levers may be irrelevant.

ENDNOTES

1 Standard source on growth accounting for the OECD countries is Maddison (1995) who also discusses the history of the "residual" calculation of productivity growth.
2 This debate is reviewed by Temple (1999).
3 See Young (1995).
4 Obviously one has to qualify this comment in an open economy. If investment is financed by foreigners then the debt burden of that investment represents a reduction in future consumption with similar negative consequences for welfare.
5 See Griliches (1992) and the set of papers on service sector output measurement in the special issue of the Canadian Journal of Economics (1999).
6 See Griliches (1992) and Boskin Commission (1996) on the U.S. CPI. My comments here draw on Harris (1998).
7 Later in the paper we discuss the concept of general purpose technologies or GPTs, a good example being computers. Work by Helpman and others in Helpman (1998) has shown that system-wide technological change initiated by the introduction of new GPT's can lead to initial declines in measured MFP.
8 There are some caveats to this when discussing developing countries. In those instances, productivity and GDP per capita growth rates can diverge because of large changes in labour force participation rates as countries climb the development ladder.
9 There is a large literature on "convergence" as an explanation of growth rates. The basic idea is that convergence of income levels might be expected if there are common factors driving economic growth such as technology and similar economic policies. Evidence for the hypothesis is mixed at the national level which suggests that there is ample room for other, country-specific, explanations of economic growth and productivity. On the other hand, there is some evidence that within nations convergence is important in explaining different regional growth rates. In the Canadian case, Coulombe (1997) covers this issue and reviews the evidence.
10 See Blomstrom et al. (1996).
11 See Argotte and Epple (1990), and Bahk and Gort (1993).
12 The evidence on Canada-U.S. productivity growth differences remains controversial. The data we have suggests that Canada has done slightly better in terms of growth rates, particularly when we exclude computer equipment manufacturing from the U.S. data.

13 Theories supporting this view are sometimes referred to as "extent of the market" theories. There is an alternative set of theories based on learning by doing in which smaller and less advanced countries are disadvantaged by globalization and freer trade that force them into specialization in less advanced products where learning-by-doing is not prevalent. Recent evidence by Ades and Glaeser (1999) strongly supports extent-of-the-market theories which suggest that external demand is an important limiting factor on growth, and openness can substitute for a large domestic market.
14 Trefler (1999) has provided some evidence to this effect.
15 It is interesting that in almost two decades the arguments remain more or less the same. My MacDonald Commission study (Harris, 1985), goes over much of the same territory from the perspective of the early 1980s.
16 A useful survey of the recent work on cities, growth and agglomeration is Duranto and Puga (1999).
17 Dwyer (1995) finds this to be particularly true in a study of U.S. textile plants.
18 This is referred to as the Balassa-Samuelson hypothesis in the literature.
19 Reported in Easterly et al. (1993).
20 Denton and Spencer (1998) provide a very useful review of demographic projections for Canada and their implications for output growth.
21 A variety of projections is provided in Session II of Courchene and Wilson (1998).
22 As argued for example in *The Economist*, September 4, 1999, pp. 65-68.
23 See Jones (1998).
24 A recent paper by Ades and Glaeser (1999) has evidence on growth which is strongly supportive of this view. Their results suggest that even a low income region can attain a high growth rate by sufficient access to an external market which overcomes the inherent limitations of small regional markets.
25 I take this as the central message of the Mintz Committee on business tax reform.
26 John Helliwell's recent study (1999) makes this point using Canadian-U.S. data.
27 See Gordon (1999).
28 The historical record on leading and lagging in growth is detailed in Abramovitz (1986).
29 Some of these issues are discussed in Globerman and Harris (1998).
30 See Grady and Macmillan (1998).

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Part II
Innovation and Productivity

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7

A Tour of Innovation and Productivity: Measurement, Determinants and Policy

INTRODUCTION

INNOVATION IS THE TRANSFORMATION OF NEW IDEAS into new and improved products and processes. Innovation seemingly improves society's welfare by making consumers better off, as they enjoy higher living standards because new and better products can be purchased at generally lower prices. The main purpose of this chapter is to survey and integrate the literature on the relationship between innovation and productivity growth in order to identify knowledge gaps for future research and to ascertain concerns for economic policy. Innovation and productivity continue to be the focus of a wide range of economic analysis and policy initiatives. One basis for concern is Canada's poor performance relative to the United States. Canada suffers an innovation gap as research and development (R&D) expenditures per dollar of gross domestic product (GDP) stand at about 65 percent of comparable estimates for the United States. In addition, various measures of productivity show that average annual growth rates in Canada have been 20-50 percent below U.S. rates over the last decade. Taken individually and jointly, these two deficiencies alarm Canadians about their future prosperity, since evidence suggests that innovation investment leads to productivity gains and accompanying higher incomes.

This chapter proceeds in the following way. The next section, entitled *Innovation and Production*, sets out a framework for innovation. This section identifies knowledge as the basis for innovation, and discusses the connection between innovation and production. The section entitled *Innovation Measurement* deals with the measurement of innovation. It identifies and evaluates three fundamental variables related to innovation inputs and outcomes: the number of patents, innovation counts, and R&D spending. In this section, we also consider the relationship between these alternative measures. The section entitled *Innovation and Public Goods* examines the distinctive features of innovation.

For example, when a firm introduces a new cost-reducing process it may not be able to prevent rivals from freely using this process. The free-rider problem implies that there are spillover effects from innovation activities. In this section, we review the main empirical results and implications from the literature on knowledge spillovers. The section entitled *Determinants of Innovation* considers the elements that determine innovation. In this section, we review and synthesize seven major causes: intellectual property protection, market competition, workforce skills, international openness, management practices, financial intermediation, and geographical agglomeration. The next section, entitled *Tax Incentives and Innovation*, sets out a discussion of the tax incentives towards innovation, and notably R&D investment. In this section, we consider the utilization and effectiveness of these incentives, and place them within the context of the corporate tax system. The following section, entitled *Innovation and Productivity Growth*, summarizes empirical studies on the relationship between innovation and total factor productivity (TFP) growth. In this section, we consider the relevance of TFP growth rates and identify channels from innovation. This section also focuses on two recent, and related, developments: accelerating international knowledge spillovers, and the emerging *new economy* based on computer and communications technologies. The concluding section discusses major topics for future work on innovation and productivity. These comments are summarized into three broad categories: measurement, analysis and policy.

Innovation and Production

THIS SECTION DELINEATES MORE PRECISELY THE CONCEPT of innovation and the relationship between innovation and conventional production. Generally, innovation can be thought of as the introduction and adoption of new processes and products. Although, in the past, innovation has been narrowly identified with product and process introduction, while diffusion has been identified with adoption, most observers now recognize that any distinction between introduction and adoption is arbitrary. Transmitting the new knowledge embodied in an innovation from one producer in a particular location to another producer operating in a distinct location is as important as creating the new product or process for the first time anywhere in the world. An innovation is useless to a particular producer in a specific geographical area unless that producer knows about the innovation. Moreover, since knowledge transmission typically involves adaptation, and thereby improvement, the adapted innovation can be thought of as a new innovation. The adaptation that accompanies transmission argues against distinguishing between introduction and adoption.

In order to understand the nexus between innovation and production, it is important to define innovation more precisely. At a particular time period and geographical area, a producer transforms inputs into outputs to serve its customers. For this area and time, producer knowledge is the set of feasible input-output combinations. Formally, economists refer to this knowledge as the set of production possibilities. Innovation can then be defined as the set of new input-output combinations that are feasible in the geographical area and in the current period compared to the previous period. Innovation is the growth or accumulation of knowledge. In formal terms, it is an expansion in the size of the set of production possibilities in of the current period, compared to the previous period's set.

Both process and product innovations are included in the above definition of innovation. Product innovations lead to outputs with new attributes or greater established attributes. Process innovations lead to inputs with new attributes or fewer traditional attributes, and improved organizational features associated with the complete production and distribution process incorporating all stages from the transformation of inputs into outputs, and the delivery of outputs to customers. Process innovations of an organizational nature are usually referred to as disembodied process innovations, while the remaining process innovations are embodied in the factors of conventional production. The distinction between a new product and an improved product is often one of degree rather than kind. New product attributes, which are synonymous with additions to the number of outputs — that is, greater diversity — are often related to higher quality, as represented by a larger number of traditional attributes. For example, consider product B which is created by bundling products A and C. If the market perceives that B is a new product, it may be willing to pay a premium over and above the price that it would be willing to pay for products A and C individually. In other words, the whole may be greater than the sum of its parts. The bundled set of established attributes of B, contained within A and C separately, is considered by the market as offering new attributes.

Often, there is no clear dividing line between a new process and a new product. For example, in order to be used, new processes often require the introduction and adoption of new products, such as new equipment. Nevertheless, new processes primarily lead to cost reductions, whereas new products lead to additional cost and accompanying increases in revenue by offering customers new attributes or greater established attributes for the same (or lower) price as older products.

The introduction and adoption of new processes and products ultimately enable consumers to enjoy a higher standard of living because new and better products can be purchased at generally lower prices. Innovation seemingly improves society's welfare by making consumers better off. However, innovation is not a *free lunch*. Resources must be expended to encourage innovation, but the presumed net result increases living standards. It might be noted that meaningful increases in living standards also arise from the reduction of undesirable outputs in the economy, such as pollution, crime and disease. Hence, innovation does not have to be associated with traditional output expansion in order to improve society's welfare.

Innovation generates output supply-side effects through cost reductions associated with process innovations and through cost increases accompanying product innovations. Moreover, innovation influences the output demand-side of markets by offering customers new attributes or greater established attributes for the same (or lower) price as older products. It is difficult to underestimate the significance of innovation in society. DeLong (1998), summarizing the empirical data on standards of living, finds that: "The past six generations of modern economic growth mark the greatest break in human technological capabilities and material living standards since the evolution of language or the discovery of fire." Morck and Yeung (2000) find that a 1 percent increase in innovation, measured simply as the number of patents normalized by GDP, leads to a 0.63 percent increase in a country's living standard, measured by per capita GDP. Further, Rao et al. (2002) document that a 1 percent increase in the number of patents per million persons granted in the United States leads to a 0.63 percent increase in GDP per employed person. In general, economies where innovation has been fostered have prospered relative to countries in which innovation has been impeded. Therefore, an important broad research agenda centres on the determinants of innovation gaps among nations, and on the identification of government policies capable of reducing divergences in living standards.

INNOVATION MEASUREMENT

INNOVATION INVOLVES THE TRANSFORMATION OF IDEAS into new products and processes. Consequently, like production, it entails input-output combinations. However, unlike production processes, where conventional inputs are molded into established outputs, the innovation process utilizes such inputs as scientists, engineers, specialized equipment and structures in order to develop new products and processes. The innovation process is inherently uncertain, whereas production processes are designed to eliminate any uncertainty.[1] In addition, the innovation process is typically not undertaken independently from production. Management coordinates the creation and implementation of new products and processes in an integrated fashion with established processes and products. Translating new ideas into new profitable products is a complex, dynamic and uncertain process.

Conceptual problems associated with understanding innovation processes and practical difficulties associated with innovation measurement have led to the use of alternative variables to measure innovation.[2] Empirical studies on innovation most often use one or more of three measures of innovative activity: i) the number of patents; ii) innovation counts; and iii) research and development expenditures. The limitations of each are discussed below.

NUMBER OF PATENTS

A PATENT IS A TEMPORARY MONOPOLY AWARDED to an inventor for the commercial use of a newly invented device. For a patent to be granted the innovation must be non-trivial, meaning that it would not appear obvious to a skilled practitioner of the relevant technology; it must also be useful, meaning that it has potential commercial value. As this definition suggests, patents are output indicators of innovative activity. When a patent is granted, an extensive public document is created containing an extremely detailed and rich data set. However, there are two important limitations associated with the use of patents (Griliches 1990). First, the range of patentable innovations constitutes a subset of all innovation outcomes; second, seeking a patent is a strategic decision and, hence, not all patentable innovations are actually patented.

Patent data can sometimes over-represent innovation. Firms that have developed a new process and fear that other firms may attempt to steal their innovation by finding a different process (meeting the patent office requirements) that circumvents the innovator's patent could engage in patent *thicketing*. This involves filing patents for variants of the original patent, not because these are substantial innovations, but because they could block a competitor's attempt to circumvent the original patent. Patenting in these circumstances may be motivated primarily by a desire to increase the costs of entry facing potential rivals, in which case the major direct outcome of patenting activity is to generate monopoly profits rather than productivity improvements.

Simple patent counts, even within a narrowly defined class, are a very imperfect measure of innovative activity, because patents vary a great deal in their importance or value. Recent research has attempted to overcome this difficulty by introducing patent citations as a proxy for the importance of patents (Trajtenberg 2002). Citations are the references to previous patents that appear in each patent. Patent citations serve an important function, since they delimit the scope of the property rights awarded by the patent. Thus, if patent B cites patent A, it implies that patent A represents a piece of previously existing knowledge upon which patent B builds and over which it cannot have a claim. It should be emphasized that patent citations, as patent counts, are dependent on the innovator actually applying for and being granted a patent. Consequently, patent citations relate to the worth of a patent, but not to non-patented innovation outcomes. Moreover, citation *thicketing* serves to complement patent thicketing in attempting to foreclose competition by increasing entry costs facing potential rivals, through the requirement to cite all relevant patents.

INNOVATION COUNTS

INNOVATION COUNTS ARE LISTS OF INNOVATIONS developed by various firms and entrepreneurs. In principle, innovation counts should be the best output data because they measure all innovation outcomes. But in practice, innovation counting is difficult since there is little guidance from the economics literature on what is an innovation. Simple innovation counts, even within a narrowly defined class, are an imperfect measure of innovative activity because innovations vary in their economic value. For example, a *general purpose technology* (GPT), which refers to a major innovation that has widespread applications, leading to a general transformation of production systems, is characterized by long and varied lags from the time of introduction to ultimate effect. In addition, the long and variable lags associated with a GPT obscure its identification from other narrower technological advances. Lastly, with respect to innovations, there are no indicators comparable to patent citations currently available to help discern value.

R&D SPENDING

R&D EXPENDITURES ARE WIDELY USED as a measure of innovation. Whereas patent and innovation counts are output-based measures of innovation, R&D spending is an input-based measure. The main criticism raised by the use of R&D spending to approximate innovation activity is that it measures inputs to innovation, not innovation outcomes (as noted in Morck and Yeung, 2000, for example). This criticism is misleading. First, as previously recognized, no single indicator could possibly capture the multidimensional innovation process. In the same way, no single output or input variable could represent a multi-output-multi-input production process. Second, output-based indicators are not inherently superior to input-based ones in summarizing innovation processes. Like production processes, innovation processes involve multiple inputs and outputs. It is well known (Varian 1992) that production processes can be summarized by either a production function, which is output-based, or a requirements function, which is input-based. Both functions depict the same process. In practical terms, the choice between an output-based and an input-based representation rests on data availability, not on conceptual correctness. Of course, there may be limitations to the use of R&D data as an adequate input measure, but that is a measurement issue; in principle, input-based measures, as well as their output counterparts, are similarly able to represent innovative activity.

The knowledge gained from current R&D spending does not disappear, and in conjunction with knowledge gleaned from past R&D spending it leads to innovation outcomes in the future. Consequently, accumulated R&D spending generates new processes and products. In this sense, R&D spending is like investment expenditures on plant and equipment. Accumulated investment contributes to plant and equipment capital, which serves as an input to produce established outputs. R&D spending leads to a durable input (i.e. one that lasts for more than a single period), which in turn generates innovation outcomes. Hence, as for other forms of investment, in order to construct capital stock measures, R&D spending must be converted from current-value terms to real or inflation-adjusted terms, and real R&D spending must be accumulated over time. This calculation leads to the construction of R&D capital, a more appropriate input-based indicator of innovative activity than R&D spending. As for other forms of capital, two significant challenges complicate the construction of R&D capital stock measures: i) determining the appropriate price index for R&D spending; and ii) determining the appropriate depreciation rate for historical R&D expenditures.[3] These are outstanding research issues.

The close link between output-based and input-based measures of innovative activity has been established for a number of countries. Griliches (1990) surveys this literature and finds a strong and contemporaneous relationship between patents and R&D spending. Recently, this relationship was investigated for Canada by Trajtenberg (2000) who found that, "Regardless of the 'race' between regressors, the fact is that innovative output in Canada, as reflected in the number of patent applications filed in the United States, seems to be highly responsive to civilian R&D performed 2-3 years earlier. Thus, fluctuations in the level of R&D resources invested do manifest themselves after a while in the number of patented innovations produced."[4] This result is also confirmed by Rao et al. (2002) who find that, for 1995 and 1997, a 1 percent increase in R&D personnel per 1,000 population lead to a 0.8 percent increase in the number of patents granted in the United States per 1 million population for OECD countries.

Input-based indicators appear to be as valid as output-based indicators of innovative activity. As Globerman (2000) recognizes, observing that organizations perform relatively small amounts of R&D does not necessarily suggest that R&D is unimportant to innovation outcomes. Rather, it might suggest that conventional measures of R&D are poor proxies for the actual rate of knowledge accumulation. Even more significantly, Trajtenberg (2000) and Rao et al. (2002) show that Canadian innovation output is the outcome of R&D spending. Just as there is no free lunch in the production of established outputs, the innovation lunch bill must be paid in order to garner the fruits of new processes and products. Looking forward into the research agenda of innovation measurement, the development of an integrated dataset consisting of patents, citations, R&D expenditures and R&D capital, along with innovation counts would be an important undertaking. In addition, given the nexus between innovation and production, datasets linking the two activities should be developed at the establishment, or at least enterprise level of analysis.

INNOVATION AND PUBLIC GOODS

THE VALUE OF AN INNOVATION TO A FIRM is based on that firm having proprietary knowledge about how to make a cheaper or better product. However, knowledge, and thereby innovation — the growth or accumulation of knowledge — is different from ordinary commodities in two ways. First, knowledge can be used, or consumed, by a producer or consumer without reducing its availability to other producers or consumers. Put differently, knowledge has the particular feature of being non-depletable or non-rivalrous. It is the so-called *publicness* feature of knowledge, which categorizes it as a public good. Typical commodities do not have this publicness feature and are called private goods.

Intermediate cases between private and public goods are also possible: their use or consumption by one producer or consumer affects to some degree its availability to others. A classic case is the presence of congestion effects on roadways. For this reason, goods that cannot be depleted or for which there is no rivalry are referred to as pure public goods. Indeed, knowledge may not be a pure public good. As Morck and Yeung (2000) note, the increased use of an innovation could drive up the costs of the special inputs it requires, for example skilled workers trained to operate new equipment.

A distinction can also be made based on whether it is feasible to exclude a consumer or a producer from the benefits of a public good. Every private good is excludable, but public goods may or may not be. The patent system, for example, is a mechanism for exclusion, albeit an imperfect one, from the use of knowledge developed by others. These public good characteristics are the first way in which knowledge, and consequently innovation outcomes, differs from ordinary, or private, goods.

Non-convexities, or increasing returns to scale in production, are the second feature associated with public goods. Intuitively, a public good that affects a private good can be considered an input into the production of that private good. From the viewpoint of the private good producer, the public good is in fixed supply since public goods are non-depletable. Hence, the fixed input is a source of fixed cost. As the scale of operations increases, fixed costs are recovered over greater sales, and their impact on profit diminishes. Therefore, the return on sales increases with the scale of operations, and production is then said to exhibit increasing returns to scale.[5]

Market solutions are likely to work poorly in the case of pure public goods, and perhaps in the case of public goods generally. Market failure can occur if a firm introduces a new cost-reducing process but may not be able to prevent a rival from freely using this process. Solutions to this *free-rider* problem involve quantity-based interventions (government provisions, laws or regulations) or price-based interventions (government taxes or subsidies). For example, an innovation is protected by patent legislation, which is designed to prevent (albeit imperfectly) others from free-riding on an innovator's new process or product. Other firms may be able to use the new process, or sell the new product developed by the innovator, but they must pay a licence fee.

The free-rider problem that emanates from the public good characteristics of an innovation prevents the innovating firm from completely appropriating the benefits from its innovation because it is unable to entirely exclude others from using it. Free-riding and consequent unappropriated benefits imply external, or spillover, effects from the innovative activities of one firm to others. In this context, a spillover is a new process or product created by an individual or organization that is appropriated by others without compensating the creator (fully or even at all) for the value of the innovation appropriated. Spillovers mean that the benefits to society from an innovation extend beyond the (private) returns appropriated by the innovator. The returns to society, or social returns, relate to the benefits from the use of an innovation, while private returns only capture the benefits arising initially from the development of the innovation. Typically, spillovers associated with innovative activities generate social rates of return that exceed private returns.

Spillovers are of special relevance to Canada because a large portion of knowledge creation is conducted externally, and foreign-owned multinationals have a significant domestic presence. As noted in Globerman (2000), relatively high degrees of foreign ownership have been linked to relatively low levels of R&D intensity in Canadian manufacturing industries. Those who believe that tighter controls on foreign ownership are in Canada's economic interest have linked low R&D intensity to Canada's poor record of innovation and productivity growth. Alternatively, proponents of a non-interventionist foreign ownership regime argue that foreign-owned firms are a robust source of import of new processes and products, which reduces the need for Canadian firms to undertake costly R&D activities.

There are two important questions to consider: i) Do spillovers cause social returns to exceed private returns to innovation? and ii) How do spillovers affect indigenous innovative activity? The literature on spillovers suggests a number of findings with respect to social versus private returns. First, social rates of return to R&D investment are substantially higher than private rates of return. Indeed, social returns can be two to ten times greater than private returns. Second, social returns are higher on privately-financed R&D compared to publicly-financed R&D. In part, this reflects the non-commercial nature of much of the R&D financed and undertaken by governments. However, publicly-financed R&D is usually cost-reducing and generates spillovers for private R&D endeavours, but it also appears to *crowd-out* company-financed R&D in many industries. Third, spillovers extend beyond national boundaries, and Canada in particular benefits from significant spillovers generated by R&D investment in the United States.

Turning to the effect of spillovers on in-house innovation, the literature shows that there is no unique relationship. Generally, there is a link, but its magnitude and direction depend on a number of elements regarding spillover sources and users. Specifically, inter-industry and international spillovers act as a substitute for indigenous R&D capital. In industries with a relatively low R&D propensity, R&D spillovers discourage the performance of own R&D. However, in industries with a relatively high R&D propensity, there is a complementary relationship between intra-industry spillovers and own-R&D performance. An important set of issues for future research centres on the ability of producers to absorb spillovers, the manner in which they do it, and their timing. The problem seems especially relevant for Canada, given the prominent contribution of foreign spillovers to productivity growth in this country.

DETERMINANTS OF INNOVATION

A NUMBER OF ELEMENTS PROMOTE INNOVATION. The major ones include: i) the strength and nature of intellectual property protection; ii) the incentive structure and ability of corporate managers; iii) the extent and intensity of competition in product and factor markets; iv) the education and skill level of the workforce; v) the stability and development of the financial system; vi) the spatial agglomeration of innovative activities; vii) the openness of the domestic economy to foreign trade, foreign direct investment, and foreign knowledge transfers; and viii) the nature and effectiveness of government policies.[6] While some statistical evidence exists about these determinants, it remains thin.

INTELLECTUAL PROPERTY PROTECTION

THE PREVIOUS SECTION RECOGNIZED THAT INNOVATION has public good characteristics. Consequently, intellectual property rights legislation, such as patent legislation, has been adopted to encourage private sector provision of innovation. These laws prevent others from free-riding on an innovation. Simultaneously, however, they prevent the free flow of ideas embodied in knowledge spillovers. The ensuing reduction in knowledge diffusion retards innovative activity. Thus, intellectual property protection contains features that both encourages and discourages innovation.

Schumpeter (1950) was one of the first to recognize that innovation brings to the fore the operative trade-offs between static efficiency and dynamic efficiency. Static efficiency requires that prices be set in accordance with marginal costs. In the absence of innovation, the extra profit a monopoly earns is associated with an extra cost to consumers, which is statically inefficient. Consumers must pay a higher price for the patent-protected goods of the firm than they would if many competitive firms were producing them. This price is inefficient from the viewpoint of static efficiency. The monopoly profit an innovator collects from the economic rent created by the exclusive right to benefit from its innovation is not a rent in a dynamic efficiency context. This rent is the return to innovation when seen in a dynamic context. The short-term benefits of a lower price must be balanced against the long-term costs measured in terms of a reduced rate of innovation.

To disavow this trade-off between static and dynamic efficiency is to disavow the theory behind patents. Patents are awarded in order to provide the innovator with the requisite incentive to innovate. At any time, the government could unilaterally declare all patents null and void. In the short run, this will lower prices on products that previously benefited from patent protection. However, such appropriation will greatly reduce or eliminate any incentive for innovators to invest the resources that gave rise to these innovations in the first place. There is evidence (Rao et al. 2002, and Morck and Yeung 2000) that strengthening intellectual property rights will increase the number of patents. Canada has not fared particularly well in terms of intellectual property protection, ranking 27th out of 120 countries for which intellectual property protection was assessed in 1997. However, as any other country where many ideas are generated outside the borders and foreign-owned multinationals have a strong presence, Canada greatly benefits from knowledge obtained through foreign spillovers.

Models of optimal patent protection such as those developed by Nordhaus (1969), show that longer patent lives give a greater financial incentive to prospective innovators, but also slow the diffusion of innovations through the economy by inhibiting knowledge transmission via spillovers. The optimal patent life balances these two factors. In practice, however, there is an important gap in our understanding of the concept of optimal patent life.

MARKET COMPETITION

INNOVATION ENABLES A FIRM TO DEVELOP CHEAPER WAYS of producing existing goods, or to develop new ones, and forge a degree of monopoly power. Competition takes on a new dimension in the context of innovation. Firms compete to innovate as well as to cut prices, and the competition to innovate may be the more important, for successful innovation bestows monopoly profits upon the innovator. This monopoly is not protected from competitors by permanent barriers to entry, but only lasts until the next innovation arises and brings about the destruction of today's creative firm by tomorrow's entrant. Schumpeter calls this process *creative destruction*. Creative firms prosper while non-innovative firms are destroyed.[7]

Formal theoretical modeling and empirical research on the process of creative destruction is relatively new. Scherer (1992) and Geroski (1994) come to the conclusion that the process of creative destruction overstates the advantages of large, monopolistic corporations as engines of technological change. Geroski finds that firms must organize themselves to respond effectively to the opportunities and incentives to develop valuable innovations. If that is the case, it qualifies the view that established firms should be allowed to fail and to be replaced by new firms.

Acs et al. (1997) argue that new firms are essential for radical innovation, and that large established firms tend to focus mainly on incremental improvements to existing products and processes. They cite intellectual property rights as the key reason for this. Innovators have clear control over their innovation in their own firm, while innovations in a large firm are usually the property, at least in part, of the firm. However, market entry can be costly for a small firm, often ending in failure. Large firms usually have more resources and experience in market entry. Acs et al. argue that *intermediated* market entry can sometimes be the solution to this imbalance. Small radical innovators can enter a market via a large firm by selling either their output or their process to the latter. The advantage for the small innovator is that it avoids the costs of market entry. The disadvantage is that the big firm takes an ownership interest.

In Canada as in other countries with significant regulated industries, it is important that policies recognize the fact that some of the highest social costs of excessive regulation are not directly observable. Potential new services and processes that are not developed, but would have been otherwise, entail real social welfare losses. For example, it has been estimated that welfare losses resulting from regulatory delays in offering voice messaging in the United States exceeded $5.1 billion (Hausman and Tardiff 1995).

Market structure does appear to affect both the rate and direction of innovation. It is difficult to classify innovation according to firm size. Smaller firms usually rise out of pools of large-firm employment. The creation of small innovative firms is, in part, an outcome of the public-good characteristics of knowledge. Large firms are unable to completely appropriate all present and future benefits associated with their innovations from both current and potential rivals. As Rao et al. (2002) point out, competitive markets are highly correlated with a higher R&D spending propensity and more patents in force. The correlation coefficient is around 0.70. In a Canadian context, Baldwin (1997) uses census data to document that mobility and turbulence are ever more often the rule, and that long periods of stability are likely to be less frequent. However, there is very little empirical evidence generally, and especially in Canada, on the role of market competition in the innovative process.

WORKFORCE SKILLS

HUMAN CAPITAL IS THE KNOWLEDGE HELD BY INDIVIDUALS that makes them valuable to an economy. Becker (1962) advanced this concept. He regards human capital as a critical input to production, as well as to innovation. There is a clear relationship between a country's stock of human capital, usually measured by the educational attainment of its population, and per capita national income (Morck and Yeung 1999). Rao et al. (2002) find that the correlation between R&D personnel per capita and the number of patents per capita granted in the United States for OECD countries is 0.77. The average resident of a high-income country is better educated than the average resident of a low-income country. One interpretation of this result is that an educated population improves a country's standard of living; but another might be that wealthier countries spend more on education.

Fagerberg (1994) surveys empirical studies of the importance of technology gaps for observed differences in economic growth across countries. He finds a consistent pattern whereby lagging countries can converge towards higher-income countries, but only if they reach a threshold number of individuals able to manage the necessary resources. He argues that investment in education is an important complement to economic growth.[8]

Human capital and physical capital appear to be complementary rather than substitutes in most firms. Using country-level OECD data for the period 1971-87, Ochoa (1996) finds that physical capital accumulation in the manufacturing sector boosts that sector's long-run growth rate when it intensively employs full-time research scientists and engineers. Thus, the data are consistent with the view that R&D efforts positively influence the marginal product of physical capital, such that diminishing returns do not necessarily come to moderate the positive effects of rapid physical capital accumulation.

Globerman (2000) notes the conventional wisdom that universities and technical colleges can promote the productivity-enhancing effects of innovation by, among other things, encouraging the dissemination of laboratory results towards industrial practice. In principle, government research institutions can play the same role, although the absence of a teaching function deprives them of one channel for faster commercialization of innovation, namely the migration of students into industry. There is a significant gap in our understanding of the relationships between skills and innovation, along with the role of academic environments, as conditioning factors of a country's performance in influencing the rate and direction of innovation.

INTERNATIONAL OPENNESS

THE AVAILABLE EVIDENCE TENDS TO PROVIDE overwhelming support for the argument that international trade, foreign direct investment and international spillovers are important channels for the diffusion of new products and processes. In addition, smaller countries like Canada benefit disproportionately from international knowledge flows. Potential channels for the international transmission of knowledge include: i) imports of capital goods and intermediate inputs; ii) foreign direct investment; iii) joint ventures and strategic alliances; iv) technology licences; v) migration of skilled labour; and vi) information flows. Some studies have attempted to evaluate the robustness of these various channels of international knowledge transfer, although most do not address the issue in any comprehensive manner.

Gera, Gu and Lee (1998) study imported information technology (IT) products. In particular, they conclude that international R&D spillovers from the IT sector played a dominant role in Canada over the period 1971-93. Bernstein (2000b) underscores the importance of international R&D spillovers to Canadian industries. Specifically, he finds that Canadian manufacturers substitute knowledge from U.S. manufacturing spillovers for domestic R&D. Spillovers from the United States cause domestic manufacturing production to become more plant and equipment intensive.

Industry-specific studies further support the view that the importance of specific international channels of technology transfer is *context-specific*. For example, international cooperative alliances represent a particularly important means for firms to strengthen their innovative capabilities in biotechnology (Bartholomew 1997). Whether this will remain true as major multinational companies emerge as important suppliers of biotechnology products is a matter for speculation. More generally, while the available research strongly suggests the existence of international spillovers to Canada, the ways in which firms, especially small- and medium-sized ones, assimilate and use new foreign-sourced knowledge have not been studied extensively.

MANAGEMENT, INTERMEDIATION AND AGGLOMERATION

THE REMAINING THREE DETERMINANTS OF INNOVATION discussed in this section are management decision-making, financial intermediation, including venture capital, and spatial agglomeration.

Managers that encourage innovation generally use incentive structures that i) give innovators property rights over some of the profits generated by their innovation; and ii) provide employees with the support needed for innovation to occur. Although these two conditions appear to be obvious prerequisites to encourage innovation within firms, research into actual property rights schemes, and managerial environments within innovating firms has been limited so far. Morck and Yeung (2000) identify one managerial environment that could affect innovation. They argue that management decision-making approaches, such as capital budgeting techniques, contain risk-taking predispositions that may shape the innovative potential of managers. This is an interesting notion that awaits further research.

Financial intermediation generally promotes innovation by enabling risk to be spread among many investors. Conversely, it is also true that innovation and ensuing growth foster financial intermediation. Levine (1997) surveys the literature and concludes that there is a strong positive link between the extent of financial intermediation and long-run economic growth. Economic growth generates the capital needed to create financial intermediaries, while the growth of financial intermediaries accelerates overall growth by enhancing the allocation of capital.

Without extensive financing mechanisms for R&D undertaken by individuals or firms lacking a reputation for successful innovation, innovations could be mostly complementary to existing products and processes rather than radically new innovations. Venture capital firms are the most important source of funds for distinctly new innovations (Kortum and Lerner 1998). Venture capital funds are pools of money destined for innovations. Typically, venture capital funds focus on a particular field and hire in-house experts (in order to guarantee confidentiality to prospective innovators) to evaluate investment proposals.

As Morck and Yeung (2000) point out, Canada has too few innovators in any given area to justify that a fund hire appropriate in-house scientific specialists. Consequently, Canadian venture capital funds are less able than their U.S. counterparts to assess the viability of investment proposals. Canadian venture capital funds thus expose their investors to more risk than do U.S. funds, and to compensate for this higher risk, they charge innovators higher interest rates than U.S. venture capital firms. Canadian innovators are better off seeking financing in the United States, which then decreases the average quality of innovation projects submitted to Canadian venture capital funds.

One solution to the venture fund scale problem would be to allow more extensive foreign investment by Canadian venture capital funds. However, as Globerman (2002) recognizes, there is no presumption that concentration of both venture capital sources and innovation implies that government policies encouraging the former will lead to the latter. It is an open research question whether venture capital sources follow the emergence of innovation centres rather than substantially contributing to the creation of these centres.

The last issue discussed in this section relates to geographical clustering of firms as a cause of innovation. Spatial proximity of like activities, or agglomeration, has many different dimensions. For example, horizontal clusters involve firms operating in the same industry, while vertical clusters define input suppliers locating in the vicinity of their downstream customers. Of course a whole range of clusters exhibit both horizontal and vertical features.

There is an extensive literature on the growth-enhancing features of agglomeration within cities, but the nature of the relationship between clustering and innovation remains subject to considerable controversy. A positive feature of clusters is that they might reduce the moral hazard problem associated with investing additional resources in non-fungible human capital. For individuals, clusters lower the risk of having to find unrelated work. This feature makes employees more willing to invest in technology-specific human capital, thereby improving their productivity. On the negative side, however, cluster congestion may lead innovative firms to move out. An adverse selection problem arises here because locating within a cluster exposes firms to unwanted employee turnover. Consequently, the weakest firms in a cluster are the ones for which the cluster is the most beneficial, and the strongest firms in a cluster are the most likely to depart.

Since spatial agglomeration is endogenous, innovations attract clusters of firms, as well as the reverse. Clusters enable firms to benefit from the spillover of ideas and the presence of skilled-labour pools. However, spillovers also form part of the costs of locating in a cluster since ideas are leaked and it is relatively cheap for employees to leave, thereby reducing cluster size. Lastly, in certain industries grounded more in information flows than in the flows of physical commodities, developments such as the Internet may diminish the importance of clusters as geographical proximity becomes less significant. Much more research is required to properly investigate cluster formation and their optimal size in relation to innovation.

Tax Incentives and Innovation

THE PUBLIC GOOD CHARACTERISTICS of innovation potentially lead to market failures, and to a divergence between social and private rates of return. A significant concern of policymakers for decades has been the selection of effective instruments to facilitate innovation. Canada, as well as other countries, employed a number of alternative policy instruments. One set of policy initiatives focuses on tax incentives. An appealing feature of tax-based subsidies is that it lets private-sector innovators choose their own R&D activities to conduct.

In this section, we discuss the role of Canadian tax-based incentives directed towards R&D.

Government targeting of projects may be thought of as relatively more effective than tax incentives. In practice, asymmetric information inherent to the knowledge creation process between R&D performers and government officials undervalues many government programs.[9] However, there are also significant problems associated with tax-based incentives. Probably the most serious challenge centres on optimal subsidy determination. Calculating an optimal R&D subsidy requires, *ceteris paribus*, equality between marginal social cost and marginal social benefit. In this context, it would require comparing the marginal return to private-sector R&D at the societal level to the opportunity cost of using additional tax revenues (for example, to fund employment insurance). This is a daunting task. Usually, rather than considering optimal tax-based incentives, policy evaluations of R&D subsidies proceed in a more limited fashion by comparing additional R&D expenditures to the loss in tax revenues. Before examining the results from policy evaluations, our discussion will first focus on the various subsidies available to Canadian R&D performers.

The treatment of tax-based subsidies for R&D varies among countries and over time (see KPMG 1995). Bernstein (2000a) has recently described Canadian tax incentives. Canada has used three different types of R&D tax incentives to encourage R&D investment. The first is accelerated depreciation of R&D expenditures. Since 1961, 100 percent of R&D expenditures can be deducted from taxable income in the current year or in future years. The second type of incentives, the tax credit, was introduced in 1977; it reduces the amount of taxes payable by a portion of R&D expenditures. From 1978 to 1982, the R&D tax credit was 10 percent of R&D expenditures for most firms, and in 1983, the tax credit rate was increased to 20 percent. After 1982, firms could apply unused credits to their future income taxes for up to seven years, or to past tax liabilities for up to three years. The carry-forward provision was extended to ten years in 1987. The third tax incentive was the incremental (or special) allowances for additional R&D expenditures. If R&D spending in a year exceeded the average amount of the past three years, an allowance equal to 50 percent of these expenditures could be deducted against taxable income in the current year. This policy was introduced in 1978 and replaced by additional tax credits in 1983.

In the late 1980s, government policy became somewhat more restrictive. Narrower definitions of the types of expenses qualifying for R&D were applied from 1987, and further tightened in 1994, 1995 and 1996. Nevertheless, a comparison of R&D tax treatment among a number of countries leads to the conclusion that R&D incentives in Canada are relatively more generous (Bloom, Griffith and Van Reenen 1998, and Warda 1997). However, Canada's persistent knowledge gap relative to the United States, many Western European nations and Japan, measured in a number of ways, and particularly by the ratio of R&D expenditures to GDP, is well documented (Bernstein 2000a). R&D underinvestment persists in Canada, and this raises an issue about the effectiveness of Canadian R&D tax incentives.

Measuring the effectiveness of an R&D tax incentive involves comparing the additional R&D spending associated with the incentive (the benefit) and the foregone government tax revenue (the cost). This kind of benefit-cost ratio is only loosely connected with the gap between the marginal social return and the private return to R&D, which provides the rationale for tax-based incentives in the first place. For example, if the social return greatly exceeds the private return, society may be willing to devote more tax revenue than the R&D induced by the tax subsidy. Conversely, if the social return only slightly exceeds the private return, the tax incentive may decrease the cost of R&D and induce an excessive amount of it. The general empirical consensus is that social returns to R&D significantly exceed private returns. Thus, a benefit-cost ratio above unity generally implies a cost-effective subsidy, and an appropriate R&D policy initiative.

R&D tax policies attempt to stimulate R&D spending in two ways. First, tax incentives reduce the unit cost, or price, of R&D capital relative to other inputs; as a result, producers will substitute R&D capital or innovation inputs for production inputs. Second, R&D tax incentives lower overall costs of production, leading to output expansion for the same total cost. As output grows, demand for R&D capital increases. As noted, the additional R&D expenditures resulting from the tax incentives are the benefits, while the costs are the tax revenues foregone. Tax incentives that generate extra R&D spending equal to, or exceeding the amount of tax revenues foregone are considered cost-effective.

The benefits associated with an R&D subsidy, measured by additional R&D expenditures induced by the subsidy, depend critically on R&D responsiveness to tax incentives. Typically, R&D is at least as sensitive as factors of production to tax policies (Bernstein 2000a). This implies that the degree of effectiveness of Canadian R&D tax incentives is not constrained by the inability of firms to respond to these incentives.

The effectiveness of R&D tax incentives also depends, in part, on the extent to which they are used. In the past, there has been significant underutilization of R&D tax credits. In the early 1980s, 31 percent of R&D expenditures came from firms that had no taxable income, and 38 percent of industrial R&D expenses came from firms that used only part of their R&D tax credits. The largest firms accounted for over 70 percent of all R&D expenditures, but only 40 percent of their R&D tax credits were used. Although there was considerable underutilization of R&D incentives as actual tax credits were only half the statutory rates, Bernstein (1986) estimates that tax credits generate benefits varying from \$0.83 to \$1.73 per dollar of foregone tax revenue. Recently, Dagenais, Mohnen and Therrien (1996) also calculated that R&D tax incentives are effective. Moreover, Bloom, Griffith and Van Reenen (1998) show that the effectiveness of Canadian R&D tax incentives is consistent with findings from other countries.

These results show that the inability of R&D incentives to significantly increase R&D spending does not come from an inadequate firm response to these measures. Nor are the R&D tax incentives a drag on the economy, as they appear to be cost-effective. However, there are a number of possible reasons why tax-based incentives have not alleviated the persistent knowledge gap in Canada. One is that firms may be unable to translate R&D tax incentives into lower unit costs of R&D. For example, Canadian R&D tax incentives are only applicable to government-approved activities. A lengthy audit and approval process becomes excessively costly relative to the R&D tax advantage. These and other audit costs may induce firms to forego declaring expenditures as R&D, or to locate R&D activities in other countries.

Another reason is that the statutory incentives, although generous, may not be adequate. Indeed, R&D tax incentives in Canada have diminished in a number of ways over the past decade. For example, the definition of R&D expenditures qualifying for tax-based subsidies has been narrowed. A third reason is that, in a broader tax perspective, the burden of the Canadian corporate tax system may be relatively more onerous than in other countries. Excessively high corporate tax rates reduce the incentive to undertake R&D activities, and offset the R&D-enhancing effects of direct R&D tax-based subsidies.[10] Lastly, frequent and extensive (actual or proposed) policy revisions add to the burden of firms undertaking R&D investments, which by their nature involve lengthy time horizons and uncertain outcomes.

INNOVATION AND PRODUCTIVITY GROWTH

MEASURING TOTAL FACTOR PRODUCTIVITY GROWTH

THE MOST COMMON DEFINITION of total factor productivity (TFP) growth is output growth after accounting for the contribution of factors of production.[11] The *extra-input*, or residual, nature of TFP prompts economists to emphasize the importance of innovation to productivity. The introduction and adoption of new processes and products improve living standards as society is able to produce output above those levels previously obtainable from factors of production. Although resources must be expended to innovate, typically the net effect leads to productivity gains.

The relationship between TFP growth and innovation emphasizes innovation that is not embodied in the factors of production. The reasoning here derives from the observation that output and input measures used to calculate productivity growth rates, should, in principle, account for new products and factors, as well as all quality improvements. Innovation embodied in traditional inputs presents a potential identification problem. Specifically, it is difficult to identify empirically the contribution of factors of production to output growth separately from the contribution of disembodied innovation. Indeed, some economists have argued that the greatest portion of innovation takes the form of improved inputs. If this measurement problem exists, it becomes difficult to separate the impact of using improved inputs from that of increased input usage, which leads to biased TFP growth rates.[12]

Another measurement problem arises in situations where innovations accompany increases in the scale of organizations. Separating the contribution to productivity of an increase in scale from the effects of implementing input-disembodied innovations is a complex task. However, this problem may not lead to an error in the measurement of TFP, but rather serve to obfuscate the relative contributions of the two components of TFP, namely disembodied innovation (a shift in the production function) and scale (a movement along the production function). Moreover, if measurement errors vary in importance over time and in different places, measured TFP becomes an inaccurate indicator of actual TFP trends among different firms, industries and countries. Although these are complex problems, measurement issues abound in economics, and these difficulties alone do not diminish the importance, albeit limited, of TFP.[13]

LINKS BETWEEN INNOVATION AND TFP GROWTH

INNOVATION RANKS PROMINENTLY in any reasonable explanation of productivity performance. There are three major avenues through which innovation affects TFP growth: i) quality improvements embodied in machinery and equipment (M&E) capital; ii) a higher skilled workforce; and iii) knowledge expansion through disembodied spillovers. First, M&E investment carries new ideas, which contribute to productivity growth by enhancing the absorption of knowledge spillovers into production and innovative activities, and by facilitating the adoption of innovation into indigenous production. Quality improvements do not occur solely through domestic investment. Similar effects are fostered through inward foreign direct investment, and from design improvements embodied in imported goods and services.

Second, improvements in human capital — a higher skilled workforce — raise productivity growth by absorbing knowledge spillovers for indigenous innovation and production, and by facilitating the adoption of innovation into indigenous production. Productivity growth from improved skills also has an international dimension, as immigrating foreign skilled-labour exhibits productivity-enhancing features.

Third, knowledge expansion from spillovers operating through various channels unrelated to factors of production improves productivity growth. These input-disembodied channels include: i) joint ventures and strategic alliances; and ii) technology licences and copyright agreements. Disembodied spillovers operate on the domestic and international fronts. For example, outward foreign direct investment facilitates the establishment of technology links for domestic firms in foreign countries.

It is worth noting at this point that explanations of productivity growth sometimes confuse the two components of TFP growth — advances from disembodied innovation, and scale economies — from its causal elements. Disembodied innovation and scale economies are by definition manifestations of TFP growth, and the causal elements operate through these two components. Put simply, the determinants of TFP gains are synonymous with the determinants of advancing disembodied technological change, and increasing returns to scale.

A common thread that characterizes the major linkages between innovation and TFP growth is the inability of innovators to completely appropriate the benefits from their innovation. Openness to new ideas promoted through spillovers, and the ability to adapt them into new products and processes lead to productivity gains. Griliches (1998) argues that spillovers account for about 75 percent of measured total factor productivity (TFP) growth in the United States. Bernstein (2000b) documents similar findings for the Canadian manufacturing sector. In the Canadian case, spillovers emanate from the U.S. economy. However, there is remarkably little empirical research, especially in the Canadian context, on the dynamic forces operating between the three innovation links (M&E quality, skilled labour and disembodied spillovers) and in their relationship to TFP growth.

We now turn to the question of how measured TFP relates to indigenous innovation? Typically, own innovation improves the diversity and quality of outputs and inputs, along with production processes. If all appropriate adjustments are made to output and input measures, disembodied indigenous innovation contributes to TFP growth. Indigenous innovation embodied in factors of production does not constitute the residual measure known as TFP growth. For example, if own innovation improves labour skills, the accompanying higher wage increases labour's share of cost. Since input cost shares are used as weights in calculating a combined input growth rate, a higher labour cost share results in higher input growth, and thereby lower measured TFP growth. Moreover, improvements due to factor-embodied own innovation are not counted as measured TFP.[14]

This view of the relationship between indigenous innovation and measured TFP enables us to interpret the general finding that own disembodied innovation exerts little influence on TFP growth. Rao et al. (2002) find that the correlation between own innovation, measured by R&D expenditures as a proportion of GDP, and TFP growth is only 0.22 for the United States and 0.31 for Canada. Mohnen (1992) reviews a number of Canadian and foreign studies and notes that there is little support for the existence of a strong link between own R&D and TFP growth in Canada, as well as in many other countries. Apart from the ubiquitous measurement problems, this result suggests that disembodied own innovation contributes little to TFP growth.

There is a further interpretation problem. Official measures of TFP typically include production inputs, as well as innovation inputs. Now, under this convention even disembodied indigenous innovation does not constitute residually measured TFP growth. Moreover, in this situation indigenous innovation only affects residual TFP growth through internally generated spillovers, such as learning by experimenting. Absent these externalities, official TFP growth rates should exhibit no significant dependence towards own innovative activities. Indeed, in a broader context, if one assumes that markets correctly price all innovation (not only currently, but for all future periods, which seems to be rather silly) and that production occurs under constant returns to scale, then one is inexorably drawn to the extreme conclusion that official non-zero TFP growth rates reflect measurement errors. In this instance, TFP growth statistics cannot reflect real, economically relevant content. Although estimates of scale economies differ among countries, the consensus view does in fact suggest significant domestic and international spillovers (Griliches 1998), and therefore measured TFP growth captures, in a limited way, changes in living standards.

Innovation and TFP Performance

MACHINERY AND EQUIPMENT QUALITY IMPROVEMENTS, higher skilled labour, and expanded knowledge flows through disembodied spillovers wield important implications for the assessment of TFP trends among nations. At its most basic level, openness to new ideas and the ability to adapt them imply in the long run that Canada's productivity trend matches that of the United States and of other like countries. However, one should not be sanguine about such longer-term projections. The same elements that propel national TFP trends contain the seeds of volatility and divergence. TFP statistics show a lack of persistent and convergent trends among countries. Indeed, Canada's productivity performance has constantly lagged the growth rates observed for the United States (Bernstein 2000a). Although there are important measurement issues relating to cross-country comparisons, the consensus appears to suggest a real and prolonged deficiency in Canadian TFP growth.

Two major developments associated with innovation influence relative national productivity trends: i) expanding international spillovers, or what may be termed accelerating *knowledge globalization*; and ii) developing computer and communications technologies, or what has come to be referred to as the emerging new economy. New ideas transmitted through international spillovers have a number of significant (positive and negative) implications for Canadian productivity. Canada relies heavily on knowledge borrowed from the United States (Bernstein 2000b). Thus, decelerating U.S. innovative activity, depicted by a slowing trend in the number of scientists and engineers engaged in R&D, will reduce TFP growth in Canada. Somewhat more subtly, Canadian and U.S. productivity growth rates diverge. There are two reasons for this divergence. First, the reduction in U.S. own R&D does not generate significant TFP losses in that country (Griliches 1998). Second, typically the United States does not extensively borrow knowledge from Canada, and is thereby relatively unaffected by Canadian innovation.

More optimistically, Griliches (1994) rejects the notion of a secular decline in U.S. R&D-induced productivity gains based on the observation that manufacturing and agricultural productivity has exhibited no secular declining trend. He argues that the linkage between R&D and productivity growth is probably more stable and more readily measured in those two sectors than in other sectors of the economy. Hence, if the contribution of R&D to productivity were declining, it should be most apparent in a faltering productivity performance in the manufacturing and agricultural sectors. This finding implies that Canadian TFP growth should accelerate and close the gap with the United States.

The globalization of knowledge intensifies international competition for skilled workers and M&E capital. This in turn affects Canadian innovation and productivity performance. Skilled workers are required to absorb new knowledge from international spillovers, and to facilitate adoption of innovation into indigenous production. M&E capital carries new ideas, which are necessary to integrate international knowledge spillovers into production and innovation. To the extent that accelerating global competition for skilled labour and M&E capital becomes important, productivity growth in Canada will depend on the ability to attract and to retain these inputs.

The exact cause of skilled labour, and M&E capital movements is uncertain. Knowledge globalization may lead to increased production and innovation specialization, which in turn generates geographic realignment of skilled workers and M&E capital. Perhaps global knowledge diffusion also reduces the requirement for skilled workers and physical capital, by enhancing the technical efficiency of each worker and machine. On the negative side, the combination of agglomeration economies and knowledge spillovers may skew the world distribution of innovation-requiring inputs, thereby dramatically reducing productivity growth in the have-not countries and increasing national productivity differences. In these cases, preventing or compensating for deficiencies in domestic skilled labour and M&E capital become paramount policy concerns.

Turning to computer and communications developments, recent evidence shows that TFP growth has surged from the early 1990s (Jorgenson and Stiroh 2000). These productivity gains are mainly attributable to the decline in computer prices since 1995. However, Gordon (1999) argues that apart from the computer industry, TFP growth in non-farm private businesses declined between 1995 and 1999 relative to the period 1972-95. It is still too early to tell whether productivity gains from information technology will persist and diffuse throughout the U.S. economy. Preliminary evidence (CSLS 2000) supports an optimistic outlook. The decline in the price of computing power encouraged substitution away from relatively expensive labour and non-computer inputs towards computers.

If information technology and the resulting new economy lead to sustained productivity benefits in the United States, the implications for Canadian TFP growth are extensive. Spillovers from the United States suggest that Canada will benefit and reap similar productivity gains. However, Canada does not rely solely on foreign technological advances. The strong domestic communications manufacturing industry indicates that Canadian TFP growth will also accelerate from internally-driven information technologies. Trajtenberg (2000) finds that the number of Canadian communications patents is only slightly below the number of communications patents in the United States, and Canadian patents have a relatively high quality. Bernstein (2000b) focuses on spillovers associated with R&D activity in the communications equipment industry and finds substantial spillovers from this industry to the Canadian manufacturing sector. Spillovers from communications equipment account for about 9 percent of average annual manufacturing TFP growth in Canada.

If productivity gains from the new economy are sustained, rising growth from the communications infrastructure could reasonably be viewed as a source of accelerating knowledge diffusion. Past growth may have germinated from declining computer prices, enabling stand-alone tasks such as word processing and data management to be performed more cheaply. Sustained growth appears to ride on the breadth and depth of communications networks such as the Internet and related technologies. The Internet fosters productivity growth by reducing costs associated with distance and search. Electronic networks enable firms to improve along many dimensions, for example input-procurement practices, inventory control, distribution methods, marketing campaigns, and customer service. The Internet reduces the constraints linked to geographical location and eliminates inefficiencies from informational discrepancies.

Resulting worldwide spatial and knowledge arbitrage through electronic networks could promote competition and innovation.

Conclusion

IN THIS CHAPTER, WE SET OUT to discuss the following issues: i) How does innovation relate to conventional production processes? ii) What particular factors affect the returns to innovation? iii) What are the major determinants of innovation? iv) How effective are tax policies designed to stimulate innovation? and v) How does innovation affect productivity growth? Serious gaps in our understanding of innovation cause considerable uncertainty about the answers to these questions. The uncertainty arises from data limitations and from our inability to interpret the available evidence. Further, these difficulties combine to impede future policy development over innovation and productivity, and consequently over the prospects for prosperity.

Within a broad perspective, there is a general consensus on some issues addressed in this chapter. First, innovation involves inputs and outputs, inextricably connected to production possibilities, and characterized by an uncertain and dynamic process generally referred to as creative destruction. Second, there are significant knowledge spillovers from innovation extending beyond national boundaries, generating productivity benefits and social returns that greatly exceed private returns. In turn, spillovers influence the incentives, and ability to undertake innovation. Third, attributes of the domestic economy (such as intellectual property protection, skilled labour and a competitive environment) and international openness (through trade, direct investment and strategic alliances) are the main driving forces behind innovation. Government tax incentives directed towards innovation, and particularly R&D investment, are cost-effective, but the overall efficacy of measures aimed at encouraging innovation must be gauged in the context of the international competitiveness of national corporate tax regimes. Fourth, innovation is a leading contributor to productivity performance. Innovation influences productivity growth through new knowledge embodied in machine and equipment investment, from hiring skilled labour, and from non-input related activities such as strategic alliances.

Our overarching consensus framework indicates few hard findings in this area of analysis. One may be optimistic or pessimistic about this state of affairs — the proverbial half empty or half full glass; irrespectively, the devil is in the details. Suggestions towards improving our ability to obtain more conclusive results hinge on improvements to available data, and on a sensible research agenda.

A number of data/measurement problems must be solved. First, an innovation data system should encompass both innovation outcomes and innovation inputs. This means that innovation and patent counts, citations, and the components of R&D expenditures (nominal and real) should be integrated and defined at the establishment or at least the enterprise level. Second, the most pressing and difficult measurement problem is the conversion from nominal to real values for innovation outputs and inputs. One solution may be to use stock market values. However, these values may have a speculative component unrelated to innovation. Alternatively, asymmetric information between innovators and financiers imply that financing is often not conducted through stock markets but through venture capital funds. The significance of venture capital funds as a valuing guide suggests that financing sources should be integrated into innovation surveys in order to help separate nominal values into the price and quantity components of innovation. Third, innovation inputs consist, in part, of various types of skilled labour. The durability of these inputs beyond a single production and innovation period requires the development of data on human capital. Skilled labour is a form of capital and it should be treated in innovation (and production) accounts like equipment and structures. Lastly, in order to analyze the innovation-productivity nexus, innovation accounts need to be integrated with production accounts.

In part, the difficulties surrounding available data are not measurement-related, but rest on the fragility of the economic analysis framework. The great success of national income accounts and input-output tables stems from their grounding in economic models. Research on innovation is still relatively young, and probably more complex than in other areas. So it is not surprising that well-defined frameworks are still lacking. In this regard, theoretical work on macro models of endogenous growth, and micro models on creative destruction, along with empirical research on knowledge spillovers and sustainable development show promises of a better understanding of innovation. As for other areas of economic research, in order to formulate reliable hypotheses, empirical models should be grounded in theory. A basis for empirical research is the view that innovation results from profit-maximizing firms and entrepreneurs operating in a dynamic, asymmetric limited information environment, who are attempting to exploit gains from trade by internalizing knowledge spillovers and earning monopoly rents from scale economies associated with successful innovation. This framework highlights the essential ingredients of creative destruction, with accompanying knowledge spillovers and scale economies, as part of the innovation process.

There are specific topics that warrant attention. First, it is important to understand how innovation inputs are related to innovation outcomes. Too frequently, either innovation outputs or innovation inputs summarize the process, and the input-output relationship is then relegated to the *black box*. An important outcome of this research would be to provide information on the importance of economies of scale in the innovation process. A second topic concerns the role of knowledge spillovers in innovation. Here, researchers should focus on how innovators integrate spillovers to the innovation process. Spillovers affect innovation input proportions, such as the composition of skills among knowledge workers, and the diversity of innovation outcomes, such as the composition of product and process technological advances, or the distribution between far-reaching and incremental innovations. Third, researchers should investigate how production processes using both new technologies embodied in machinery and equipment investment and higher skilled labour interact with innovation processes. This issue underscores the fact that innovation does not occur in a vacuum, but is intimately tied to production decisions, and thereby to the profit-maximizing calculus. An important policy consideration here is the effectiveness and efficiency of tax policy. Tax incentives directed towards innovation operate within the overall corporate tax structure, and determining the success or failure of these incentives requires an understanding of the linkage between innovation and production. Fourth, a topic relating to production and innovation concerns the production of goods and the use of services. Purchased services, as intermediate inputs, serve as a significant and expanding means of knowledge diffusion throughout the economy. One particular aspect of this issue involves outsourcing, but another and perhaps more significant aspect for Canada entails international trade in services and its implications for innovation. Innovation and product demand conditions represent a fifth topic. The ability of innovators to shift customer demand in their favour is a major endogenous determinant of market structure and of monopoly rents associated with innovation. Lastly, the communications infrastructure through accompanying network effects fosters innovation. It is important to study the role of communications networks, such as the Internet and related technologies, on the rate and direction of innovative activity. Another application of government policy presents itself here. If the communications infrastructure yield significant externalities, how do governments enter the picture: through provisioning, as for roads and highways, or through pricing, as for residential telephone rates, or perhaps by ensuring a competitive marketplace?

The significance of innovation to society cannot be underestimated. As Schumpeter (1950, p. 83) wrote, "The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates."

ENDNOTES

1 Uncertainty arises in conventional production with respect to product demand conditions facing producers and, on the cost side, through such things as climate. However, the process by which traditional inputs are transformed into established outputs is known.

2 Since innovation is the change in the stock of knowledge, it is possible to measure the value of the stock of knowledge of publicly-traded firms by subtracting the sum of the net physical and financial capital from the equity market valuation. However, there is the problem of converting an estimated value into a real magnitude.

3 Griliches (1979), Bernstein (1985), and Mohnen (1992) discuss these issues further.

4 The patent data relates to Canadian patents granted in the United States, which is a much larger number, and is therefore more representative of innovative outcomes than Canadian patents granted in Canada.

5 Caves (1982) also provides an overview of this topic as it is applied to the determinants of innovation.

6 The section entitled *Tax Incentives and Innovation* discusses government policies focusing on tax-based incentives towards innovation.

7 Hobijn and Jovanovic (2000), using stock market evidence, find that incumbents resisted the information technology revolution. This caused their value to fall.

8 Ochoa (1996) presents a different view. He finds that the rate of growth (as opposed to the stock) of a country's human capital is not strongly related to overall economic growth. One way to reconcile Ochoa's finding with other results is to consider that, for any period, human capital investment is quite small compared to a country's stock of human capital.

9 Cohen and Noll (1991) provide examples from the United States where federal R&D projects have frequently continued to the point where expected marginal social costs exceeded expected marginal social benefits.

10 International differences in personal tax regimes, including the treatment of capital gains, may also serve to retard R&D incentives. However, there are no studies looking carefully at this issue.

11 In this context, inputs include labour, plant and equipment. TFP growth is also referred to as multifactor productivity growth. In addition, there are partial productivity indicators. For example, labour productivity growth measures output growth net of labour input growth.

12 Theoretically, it is possible to define TFP in constant-quality terms. Practically, this is not a realistic option. In any event, constant-quality TFP measures limit comparisons over long periods and for many countries, since TFP would have to be conditioned on a common quality basis.

13 Some economists, such as Lipsey (1996), consider that TFP is a meaningless concept. In our own view, TFP accounts for a specific form of innovating activity and, in addition, for scale economies that exist in production.

14 However, in terms of a causal link to TFP growth, there may be own spillovers internalized from factor-embodied indigenous innovation. One example may be learning by experimenting, where new ideas arise unexpectedly through experimental trials. Absent these spillovers, there is no causal link to measured TFP growth.

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8

Is Canada Missing the "Technology Boat"? Evidence from Patent Data

SUMMARY

CANADA HAS BEEN LAGGING in terms of productivity growth in recent years. A possible cause might be poor performance in R&D and technical change. This paper is an attempt to shed light on this issue, by examining innovation in Canada over the past 30 years with the aid of highly detailed patent data. For that purpose, the author uses all Canadian patents taken in the United States (over 45,000), as well as U.S. patents and patents from other countries for comparative purposes. Canadian patenting is highly correlated with lagged R&D, and with world-wide developments in technology as reflected in total U.S. patenting. Canada stands mid-way among the G-7 countries in terms of patents per capita and patents/R&D, but in recent years it has been overtaken by a group of "high tech" countries: Finland, Israel and Taiwan, with South Korea closing-in fast. The technological composition of Canadian innovations is rather out of step with the rest of the world, with the share of traditional fields still very high in Canada, whereas the upcoming field of computers and communications has grown less in Canada than elsewhere. Given that the computers and communications group is the dominant "general purpose technology" of the present era, weakness in this area may impinge on the performance of the whole economy. Another source of weakness lies in the pattern of ownership of the intellectual property represented by patents: less than 50 percent of Canadian patents are owned by Canadian corporations, a much lower percentage than all other G-7 countries. In terms of the relative "quality" of Canadian innovations, as measured by the number of citations received, it is significantly lower than the quality of patents awarded to U.S. inventors, particularly in computers (but not in communications), and in medical instrumentation (but not in drugs).

INTRODUCTION

CANADA STANDS OUT AS A HIGHLY ADVANCED ECONOMY in terms of income per capita as well as various measures of quality of life. Yet, in recent years, it has stalled and even lost ground relative to other countries (particularly the United States) in terms of productivity and growth (see, for example, Trefler, 1999). This seemingly incongruent predicament has elicited a great deal of attention, and motivated research aimed at understanding the sources of the current "malady". One of the possible lines of inquiry in this respect is to investigate the performance of the Canadian economy in terms of R&D, innovation and technical change. After all, these are the key factors that have traditionally propelled productivity growth in the industrialized world.

This paper is an attempt to shed light on the innovative performance of Canada with the aid of highly detailed patent data, drawn from all patents granted in the United States to Canadian inventors, and to U.S. patents granted to other countries. I shall address questions such as: How does Canada fare vis-à-vis other countries in terms of patenting activity? What is the technological composition of its innovations? Who actually owns the intellectual property rights, and to what extent can the Canadian economy expect to benefit from the innovations of Canadian inventors? How do Canadian innovations compare to those of other countries in terms of their "importance" as reflected in patent citations? In addressing these questions we hope not only to shed light on the case of Canada, but also to demonstrate the power of this type of data for studying innovation in great detail and, in particular, for examining in a comparative fashion the innovative performance of countries and regions.

Why the focus on Canadian patents in the United States? Several reasons account for that. First, according to Rafiquzzaman and Whewell (1998), "Canada has one of the lowest propensities to file patents at home of any of the major industrialized countries, with only 6.6 percent of national patent applications originating from residents in 1992" (p. 5). Thus, a natural place to look for the outcomes of innovative activity in Canada is in the patenting abroad by Canadians. The lion share of patent applications abroad has traditionally gone to the United States (well over half for most of the period studied), due primarily to the high level of economic integration between Canada and the United States.[1] Second, even though Canadian patenting in other G-7 countries has increased significantly over the years (Rafiquzzaman and Whewell, Table 2), it is often the case that patents are sought first and foremost in the United States, where the standards for patentability are more stringent that in most European countries. Thus, one can hopefully learn a great deal about innovation in Canada by analyzing the Canadian patents granted in the United States. From the mid 1960s through 1997, Canada-based inventors received over 45,000 patents in the United States. This is a large (absolute) number, placing Canada as the 5th largest foreign recipient of U.S. patents.

Adam Jaffe and I have developed in recent years a methodological approach that allows the study of innovation in great detail with the aid of patent data, and not just by relying on patent counts.[2] In particular, building both on detailed information contained in patents and on patent citations, we are able to compute, for each individual patent, quantitative indicators of notions such as the "importance", "generality", and "originality" of patents (Jaffe, Henderson and Trajtenberg, 1997). We can also trace the "spillovers" stemming from each patent, and analyze their geographical and temporal patterns (e.g. are spillovers geographically localized? See Jaffe, Henderson and Trajtenberg, 1993). Moreover, we have constructed a large data bank containing information on all U.S. patents granted from 1965 to 1996,[3] that allows us to compute this sort of measures for any subset of patents. This is a powerful capability that greatly enhances our ability to do empirical research in the area of the economics of technical change.

The paper is organized as follows. Beginning with a concise discussion of the data, we then examine the main trends in Canadian patenting, both in itself and in comparison to two groups of countries, the other G-7, and a "reference group of countries" consisting of Finland, Israel, South Korea and Taiwan. The next section deals with the technological composition of Canadian innovations, relative to that of other countries. Then, we look at the distribution of Canadian assignees, thus addressing the issue of who controls the rights to the intellectual property embedded in these patents, and hence who can expect to benefit from it. The last section undertakes to examine the relative "importance" or "quality" of Canadian patents vis-à-vis patents granted to U.S. inventors, in terms of citations received. Finally, we summarize the main points and attempts to draw policy implications.

THE DATA

A PATENT IS A TEMPORARY MONOPOLY AWARDED to inventors for the commercial use of a newly invented device. For a patent to be granted, the innovation must be non-trivial, meaning that it would not appear obvious to a skilled practitioner of the relevant technology, and it must be useful, meaning that it has potential commercial value. If a patent is granted, an extensive public document is created. The front page of a patent contains detailed information about the invention, the inventor, the assignee, and the technological antecedents of the invention, all of which can be accessed in computerized form (Figures 1 and 2).

FIGURE 1

United States Patent Allan et al.	5,946,313 August 31, 1999

Mechanism for multiplexing ATM AAL5 virtual circuits over Ethernet
Abstract
The invention provides for a E-Mux and a method for encapsulating/segmenting ATM cells into/from an Ethernet frame at the boundary between an ATM and an Ethernet network. An Ethernet end-station on the E-Mux is addressed using multiple MAC level identifiers, which are dynamically assigned according to the ATM virtual circuits which terminate on that end-station, and have only transitory significance on the Ethernet. A unique ATM OUI identifies the frames carrying ATM traffic.

Inventors:	Allan; David Ian (Ottawa, CA); Casey; Liam M. (Ottawa, CA); Robert; Andre J. (Woodlawn, CA).	
Assignee:	Northern Telecom Limited (Montreal, CA).	
Appl. No.:	821,145	
Filed:	March 20, 1997	
Intl. Cl.:		H04Q 11/04
Current U.S. Cl.:		370/397; 370/401
Field of Search:		370/397, 395, 398, 401, 471, 473, 474

References Cited | [Referenced by]

U.S. Patent Documents

5,457,681	October 1995	Gaddis et al.	370/56
5,490,140	February 1996	Abensour et al.	370/397
5,490,141	February 1996	Lai et al.	370/397
5,732,071	March 1998	Saito et al.	370/410

These extremely detailed and rich data have, however, two important limitations: first, the range of *patentable* innovations constitutes just a sub-set of all research outcomes, and second, patenting is a *strategic* decision and hence not all *patentable* innovations are actually *patented*. As to the first limitation, consider an hypothetical distribution of research outcomes, ranging from the most applied on the left to the most basic on the right. Clearly, neither end of the continuum is patentable: Maxwell's equations could not be patented since they do not constitute a device (ideas cannot be patented). On the other hand, a marginally better mousetrap is not patentable either, because the innovation has to be non-trivial. Thus, our measures would not capture purely scientific advances devoid of immediate applicability, as well as run-of-the-mill technological improvements that are too trite to pass for discrete, codifiable innovations.

FIGURE 2

United States Patent	**5,941,683**
Ridyard et al.	**August 24, 1999**

Gas turbine engine support structure

Abstract

A bearing support structure for a gas turbine engine comprises an annular array of stator vanes and a radially inner bearing support portion which are interconnected by an annular array of radially extending U-shaped cross-section parts. The U-shaped cross-section parts are interconnected at their radially outer extents and are arranged so that adjacent parts are open in generally opposite axial directions. Such a bearing support structure can carry service pipes with good accessibility and be produced by casting, thereby reducing its cost.

Inventors:	Ridyard; Philip (Mississauga, CA); Foster; Alan G (Derby, GB).
Assignee:	Rolls-Royce plc (London, GB).
Appl. No.:	25,109
Filed:	February 17, 1998
Intl. Cl.:	F01D 25/16
Current U.S. Cl.:	415/142; 415/209.2; 415/209.3; 415/209.4; 415/210.1; 416/244.A
Field of Search:	415/142, 209.2, 209.3, 209.4, 210.1; 416/244 A, 245 R; 60/226.1

References Cited | [Referenced by]

U.S. Patent Documents

4,979,872	December 1990	Myers et al.	415/142
4,987,736	January 1991	Ciokajlo et al.	60/39.31

The second limitation is rooted in the fact that it may be optimal for inventors *not* to apply for patents even though their innovations would satisfy the criteria for patentability. For example, until 1980 universities in the United States could not collect royalties for the use of patents derived from federally funded research. This limitation greatly reduced the incentive to patent results from such research, which constitutes about 90 percent of all university research in the United States. Firms, on the other hand, may elect not to patent and rely instead on secrecy to protect their property rights.[4] Thus, patentability requirements and incentives to refrain from patenting limit the scope of analysis based on patent data. It is widely believed that these limitations are not too severe, but that remains an open empirical issue.

Our working hypothesis here is that, whereas these limitations may affect *level* comparisons across categories/industries and perhaps across countries *at a point in time*, they do not affect the analysis of trends and changes over time.

In other words, if we observe a surge in the *share* of U.S. patents in the category Computers and Communications and a concomitant decline in the share of U.S. patents in the category Chemical, it is hard to believe that such movements are due to underlying changes in the relative propensity to patent in these two sectors. Rather, the assumption is that these trends reflect true changes in the amount of innovation done in those categories.

BASIC FACTS ABOUT CANADIAN PATENTING IN THE UNITED STATES

FIGURE 3 SHOWS THE NUMBER of successful Canadian patent applications in the United States over time, starting in 1968. Patenting was essentially flat for the first 15 years and then started to increase, but not in a smooth way: the number of patents grew fast during the 1986-89 period, and then again in 1992-95, with a period of stagnation in between. We have to be careful with the timing though: patent applications reflect (successful) R&D conducted *prior* to the filing date, with lags varying greatly by sector. Thus, the number of patents in a particular year should be attributed to investments in R&D carried out in the previous 2-3 years at least, and in some sectors (such as pharmaceuticals) further back (Figure 4).

FIGURE 3

CANADIAN PATENTS IN THE UNITED STATES, 1968-97

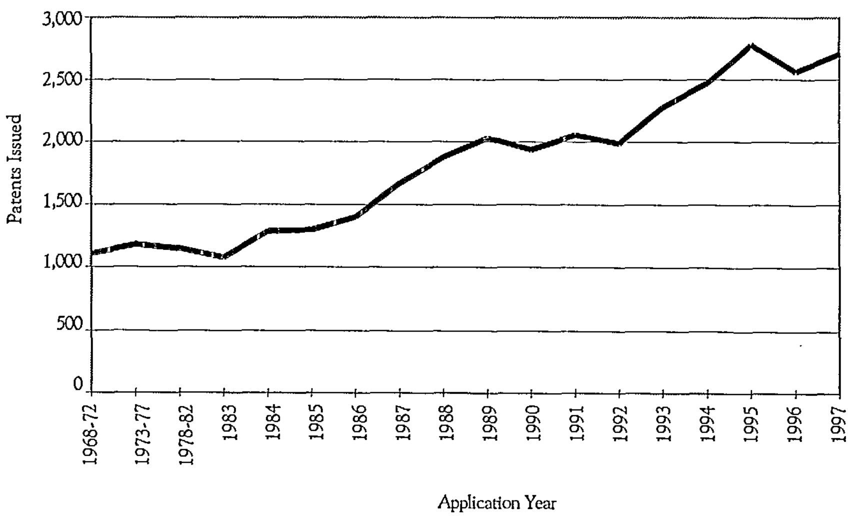
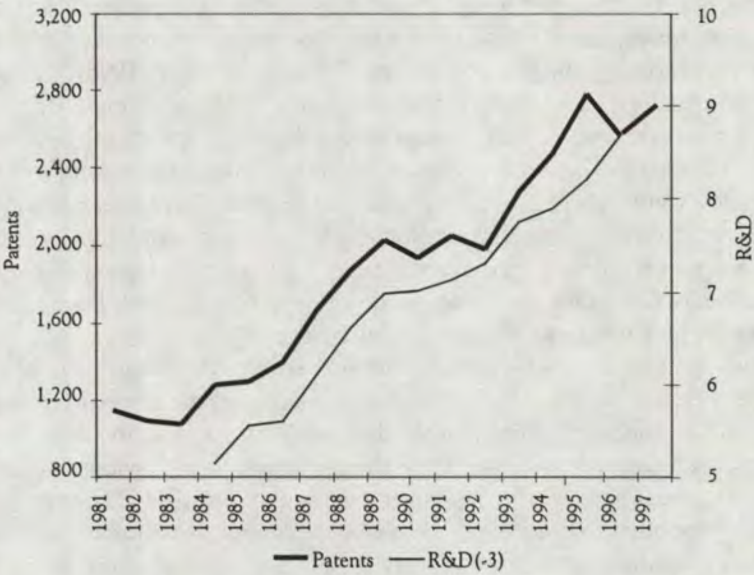


FIGURE 4

CANADIAN PATENTS AND CIVILIAN R&D EXPENDITURES (1992$ MILLIONS, 3-YEAR LAG)



	DEP. VAR: LOG (CANADIAN PATENTS), 1981-97				
REGRESSORS (IN LOGS)	(1)	(2)*	(3)	(4)*	(5) 1981-95**
Constant	4.36	-3.51	0.88	-0.36	1.94
	(27.8)	(-1.49)	(0.44)	(-0.18)	(2.15)
R&D Lagged	1.62		1.02	0.67	1.32
2 Years	(20.3)		(2.92)	(1.8)	(3.3)
Patents to U.S.		1.02	0.43	0.61	0.28
Inventors		(4.74)	(1.75)	(2.43)	(1.04)
AR(1)		0.64		0.16	
		(2.37)		(0.56)	
Obs.	15	16	15	14	13
R^2	0.969	0.966	0.976	0.975	0.976
DW	1.88	2.34	1.61	2.08	1.98

Notes: t-statistics in parenthesis
* Corrected for serial correlation.
** The patent figures for 1996 and 1997 are preliminary estimates, hence this run.

What accounts for the observed path of Canadian patenting over time? I shall not attempt to conduct here an in-depth analysis of such trajectory (that is beyond the scope of the present study), but rather I will content myself with examining the most salient factors. Let us first of all consider the input side, namely R&D: the more resources a country devotes to research and other forms of inventive activity, the more we would expect to see innovative outputs, and certainly patents among them. I shall use for these purposes *real, non-defence* R&D spending, as reported by the National Science Foundation (NSF, 1998).[5] Second, there are fluctuations in world-wide patenting quite likely reflecting changes in technological opportunities (and perhaps also in patenting practices), that may influence patenting by Canadian inventors. Moreover, given the proximity to the United States, Canadian patenting patterns may be particularly sensitive to patenting by U.S. inventors (they account for about one half of all U.S. patents). In order to ascertain the importance of these factors, I run simple regressions of the yearly number of Canadian patents as the dependent variable, with lagged R&D and patents by U.S. inventors as regressors, all in logs.[6]

As we can see, the pair-wise correlations between Canadian patents and *each* of the regressors are very high. When put together in the regression, lagged R&D prevails in some of the runs, but the data are too sparse and too collinear to allow us to reach definite conclusions. On the one hand, the behaviour over time of Canadian patent applications resembles that of patenting by U.S. inventors, apparently responding to global economic and technological forces. On the other hand, Canadian patents follow very closely the amount of resources devoted in Canada to civilian R&D. Of course, it could be that expenditures on R&D in Canada respond to the same underlying global forces that drive total patenting (e.g. technological opportunities), and hence a more elaborate model would treat R&D as endogenous. Regardless of the "race" between regressors, the fact is that innovative output in Canada, as reflected in the number of patent applications filed in the United States, seems to be highly responsive to civilian R&D performed 2-3 years earlier. Thus, fluctuations in the level of R&D resources invested do manifest themselves after a while in the number of patented innovations produced.

Beyond the statistical analysis, a closer look at the series, and in particular at the *growth rates* of patents and of R&D, reveals a number of discrete periods along the time trajectory, which seem to follow a 3-year cyclical pattern:

PERIOD	GROWTH RATE OF PATENTS	GROWTH RATE OF R&D (3-YEAR LAG)
1968-83	~ 0%	N/A
1983-86	9.2%	4.4%*
1986-89	13.2%	7.6%
1989-92	-0.7%	1.5%
1992-95	6.4%	4.2%

Note: * Computed for 1981-83 only.

The correspondence between the two series is quite striking (recall Figure 4), and raises questions about the "political cycle" that may have induced the observed fluctuations in R&D spending.

INTERNATIONAL COMPARISONS

WHEREAS THE DETAILED ANALYSIS OF CANADIAN PATENTING is revealing in itself, we resort to international comparisons in order to put in perspective the overall level and trend over time in Canadian patenting. We have chosen for that purpose two groups of countries:

1. *The other G-7*: France, Germany, Italy, Japan, the United Kingdom and the United States.

2. *A Reference Group*: Finland, Israel, South Korea and Taiwan.

The Reference Group consists of countries that have fast-growing high-technology sectors, which have become pivotal for their economic performance and in particular for growth. Thus, they provide a benchmark in terms of patenting in economies that are geared towards innovation as they try to catch up with the richer G-7-type countries.

Appendix A contains detailed patent figures for each country, Figures 5-6 show the time patterns of patents per capita for Canada versus each of the above groups of countries,[7] while Figure 7 does the same in terms of patents/R&D, for the G-7 only.[8] As these figures reveal, Canada holds a respectable mid-place vis-à-vis the G-7, both in terms of patents per capita and in terms of patents per R&D dollars: it lies well below the United States and Japan, nearly on par with Germany (higher in terms of patents/R&D), and above France, the United Kingdom and Italy. In the early seventies Canada was even ahead of Japan, but then Japan took off and is now closing in on the United States. Notice that 1983 proved to be a turning point for *all* of the largest countries (United States, Japan, Germany, and to a lesser extent Canada); this is an interesting fact in itself that remains to be explained.

The comparison with the Reference Group shows a very clear picture: Canada was well ahead of the four countries in the group throughout the seventies, but during the eighties Israel and Finland caught up, surpassing Canada by the mid nineties. Taiwan experienced a meteoric rise since the early eighties, bursting ahead of the pack by 1997. South Korea is also climbing up extremely fast, and will probably surpass Canada by 2000. It is thus clear that the countries in the Reference Group are experiencing much faster rates of innovation than Canada, reflecting for the most part conscious policies of encouragement of industrial R&D and of the high-technology sector.

FIGURE 5

PATENTS PER CAPITA: CANADA VS. THE G-7
(PATENTS PER 100,000)

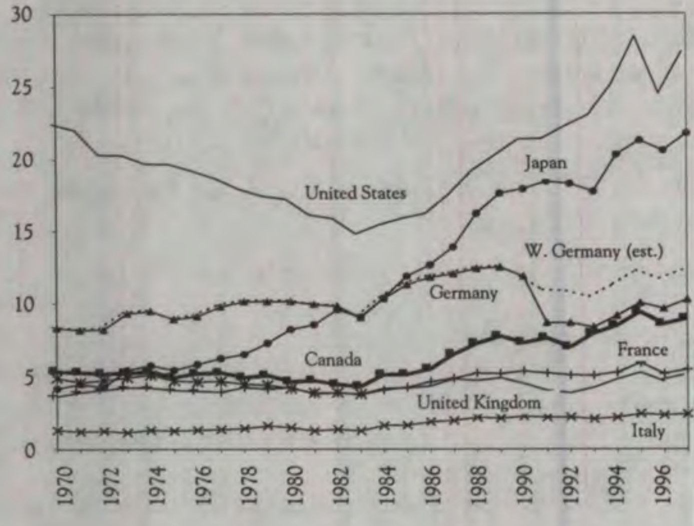


FIGURE 6

PATENTS PER CAPITA: CANADA VS. THE REFERENCE GROUP
(PATENTS PER 100,000)

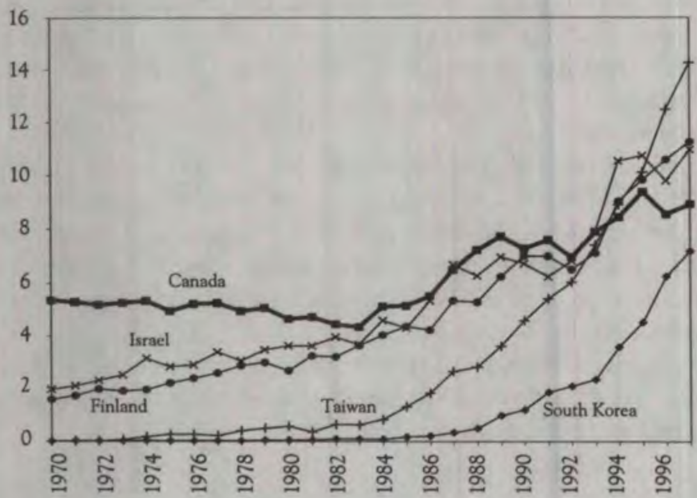


FIGURE 7

PATENTS-/NON-DEFENCE R&D IN THE G-7
(PATENTS PER 100M$ R&D)

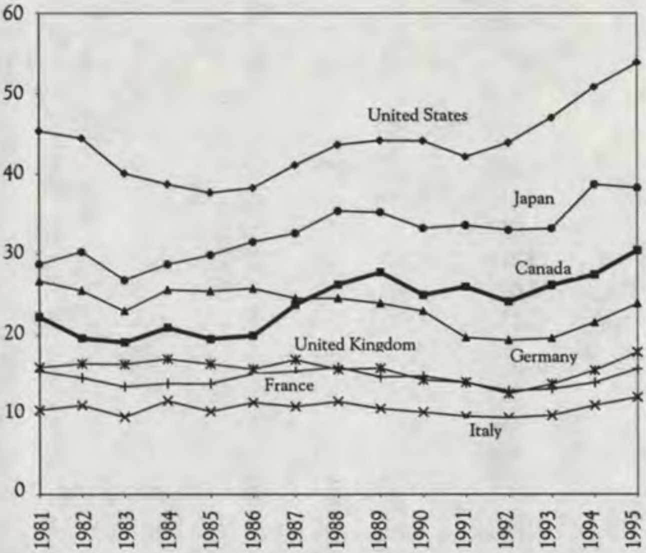


Table 1 summarizes the main statistics for these countries, including their "success rates" and growth rates in patenting, over the entire period (1968-97) and for the past five years. The picture that emerges is mixed: on the one hand, Canada experienced healthy growth rates in patenting, as compared to the other G-7 countries; for the past 30 years it was second only to Japan, and for the past five years it has the highest growth rate among the G-7. On the other hand, it still stands mid-way in terms of patents per capita (compared again to the other G-7), and second to last in the absolute number of patents. In order to improve its standing in those terms Canadian patenting would have to grow significantly faster than at present. The reference group offers a good perspective in that respect: notice that their growth rates in the past five years have been 2 to 5 times faster than Canada's.

Table 1 shows also that Canada has a relative weakness in terms of its "success rate", that is the proportion of patent applications resulting in patent grants: it stands second to last vis-à-vis the other G-7 countries (only the United Kingdom has a worse record), and below 3 of the 4 countries in the Reference Group (only Taiwan is lower) for the period 1992-97. To understand the implications of these differences, if Canada were able to reach the average of the G-7 countries ahead of it (61 percent) from the present 55 percent, that would

TABLE 1

CANADA, THE G-7 AND THE REFERENCE GROUP, BASIC PATENT STATISTICS, 1967-97

	PATENTS PER YEAR		PATENTS PER CAPITA* (%)		SUCCESS RATE (%)		ANNUAL GROWTH RATE (%)	
COUNTRY	1967-97	1992-97	1967-97	1992-97	1967-97	1992-97	1967-97	1992-97
Canada	1,552	2,560	6.2	8.6	56	55	3.6	6.4
Other G-7:								
France	2,466	3,138	4.6	5.4	66	63	2.2	1.9
Germany	6,422	7,732	9.9	9.5	65	63	2.6	3.8
Italy	959	1,323	1.7	2.3	59	58	3.2	1.9
Japan	13,515	25,474	11.8	20.3	65	61	8.6	3.8
United Kingdom	2,603	2,814	4.5	4.8	55	51	0.2	5.4
United States	47,153	67,478	19.8	25.6	62	59	1.7	5.2
The Reference Group:								
Finland	223	490	4.7	9.6	57	58	9.1	12.0
Israel	232	564	5.2	10.0	54	56	10.0	12.9
South Korea	472	2,159	1.1	4.8	61	62	34.3**	29.5
Taiwan	602	2,291	3.1	10.7	44	47	24.9**	19.7

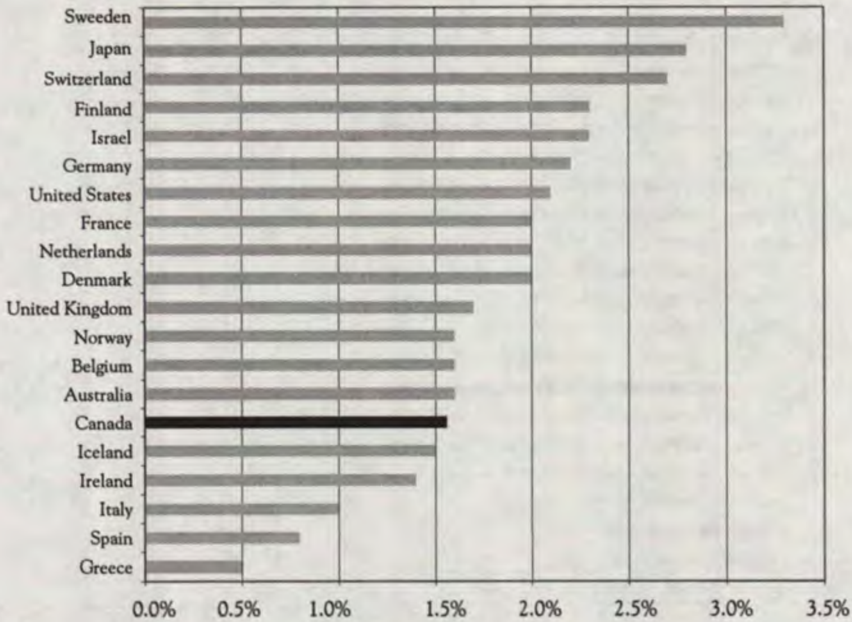
Notes: * Number of patents per 100,000 of population.
** For South Korea and Taiwan the average growth rates are for the last 20 years.

represent an increase of about 11 percent in the annual number of patents granted. This would be like an increase in the productivity of the R&D process, rather than an increase in the overall level of resources devoted to inventive activity.

It is important to note that in the present context the *absolute* number of patents remains key (similarly to the absolute level of R&D expenditures, rather than its ratio to GDP). In order to establish a viable, self-sustaining high-technology sector, a country has to achieve a critical mass in terms of pertinent infrastructure, skills development, managerial experience, testing facilities, marketing and communication channels, financial institutions, etc. Similarly, it is clear by now that spillovers, and in particular *regional* spillovers, are extremely important in fuelling the growth of this sector. Once again, the amount of spillovers generated, and the ability to capture external spillovers is a function of *absolute*, not relative size. If we take the number of patents as indicative of the absolute size of the innovative sector, Canada still has a long way to go, considering that it stands below all of the other G-7 countries except Italy, and that by 1997 Taiwan and South Korea have already moved ahead of Canada (Appendix A).

FIGURE 8A

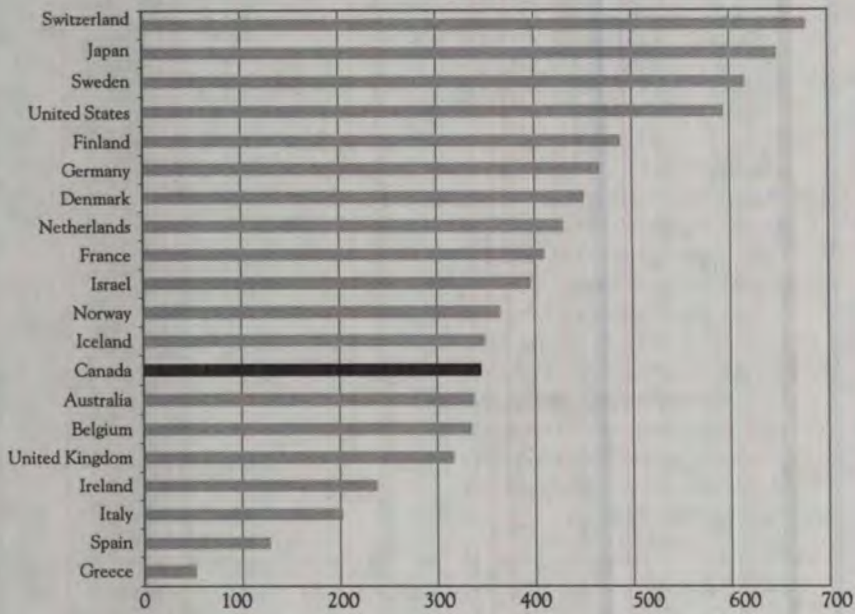
CIVILIAN R&D AS A PERCENTAGE OF GDP IN OECD COUNTRIES, 1996



Recall from the discussion in the section entitled *Basic Facts About Canadian Patenting in the United States* that there is a tight relationship between R&D spending in Canada and patenting. Comparing Canada to OECD countries in terms of R&D/GDP ratios, and in terms of R&D per capita (Figures 8A and 8B), we can see that Canada devotes a relatively modest level of resources to R&D.[9] Thus, it is quite clear that the somewhat precarious standing of Canada in terms of innovative output reflects to a large extent its weak commitment to R&D. Moreover, the implication of a *low* R&D/GDP ratio is even more problematic for Canada, considering once again that in this area the *absolute* amount of resources is what counts, and that Canada's economy is much smaller than that of the leading G-7 countries. In 1997, Canada's GNP was 38 percent that of France, 25 percent that of Germany, 12 percent that of Japan, and 8 percent that of the United States. These (much larger) countries devoted 2.0-2.8 percent of GDP to civilian R&D, as opposed to 1.5 percent for Canada.

FIGURE 8B

R&D CIVILIAN PER CAPITA IN OECD COUNTRIES
(1996$ PPP)



THE TECHNOLOGICAL COMPOSITION OF CANADIAN PATENTED INNOVATIONS

THE U.S. PATENT AND TRADEMARK OFFICE has developed over the years a very elaborate classification system by which it assigns patents to technological categories. It consists of over 400 main patent classes, and over 150,000 patent sub-classes. The main patent classes have been traditionally aggregated into four categories: chemical, mechanical, electrical and other. We have developed recently a new classification scheme, by which we assigned these 400 patent classes into 35 technological "sub-categories", and these in turn are aggregated into 6 categories: Computers and Communications, Electrical and Electronic, Drugs and Medical, Chemical, Mechanical and Others. This classification allows one to study in detail the technological composition of the flow of patented innovations. In particular, one can compare the technological portfolio of any country with world-wide trends, which is what we intend to do here with respect to Canada.

FIGURE 9

DISTRIBUTION OF PATENTS BY TECHNOLOGY CATEGORIES, ALL U.S. PATENTS

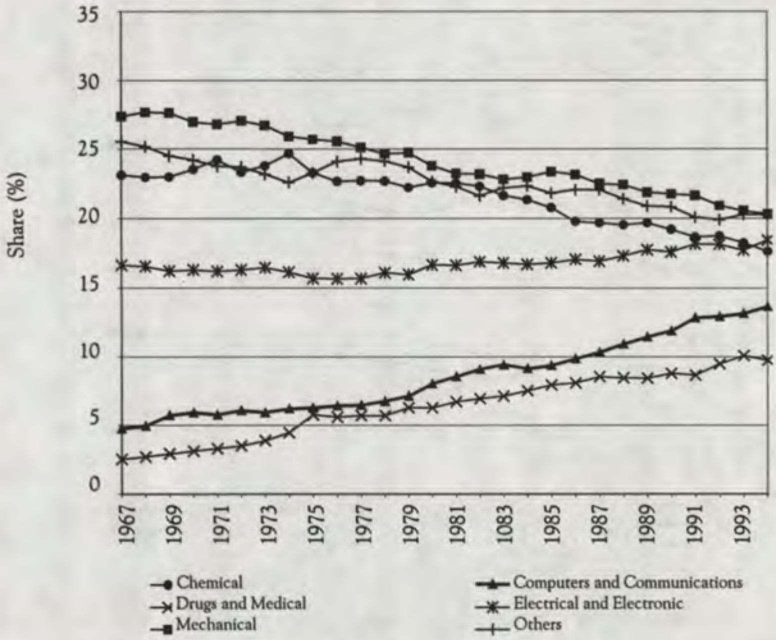
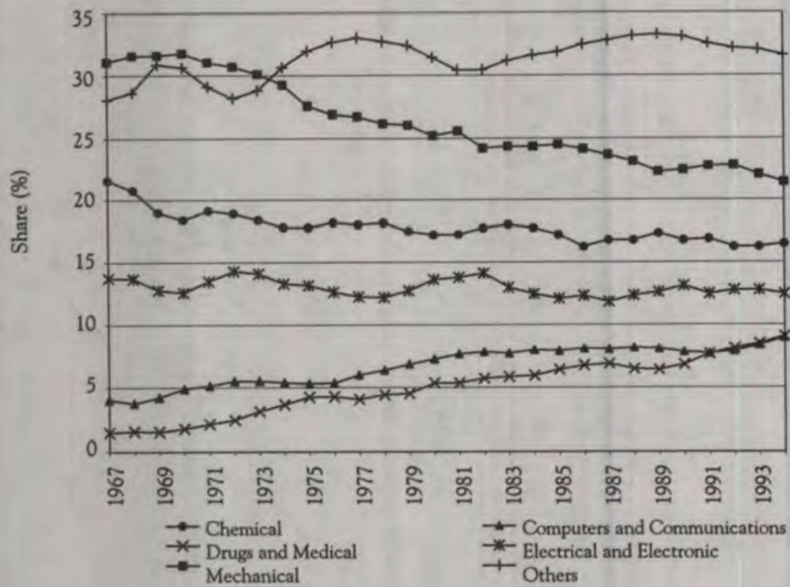


Figure 9 shows the distribution of patents over time by these six technological categories for all U.S. patents, while Figure 10 does the same for patents granted to Canadian inventors (Appendix B shows these distributions for patents granted to U.S. inventors, and to non-U.S. inventors). Figure 9 is supposed to reflect the main trends in world-wide, cutting-edge technology. The pattern is quite clear: for the first decade or so (i.e. 1967-78) there is little change — just a slow decline in Mechanical patents,[10] and a concomitant small increase in the share of Drugs and Medical. The three traditional fields (Mechanical, Chemical and Others) stand highest throughout this initial period, with shares of about 25 percent each. Both Drugs and Medical, and Computers and Communications accounted for a very small fraction back then: 3 to 6 percent each.

Starting in 1979 this mostly static picture changes quite dramatically: all three traditional fields lose ground, whereas Computers and Communications (C&C) category urges forward doubling its share (from 7 percent in 1979 to 14 percent in 1994), and Drugs and Medical also increases rapidly from 6 to

FIGURE 10

DISTRIBUTION OF PATENTS BY TECHNOLOGICAL CATEGORIES, CANADIAN INVENTORS



10 percent (12 percent in the United States). As to Electrical and Electronic, it increases slightly during this period, from 16 to 18 percent. It is important to remark that these changes in shares are all the more significant in view of the fact that there has been an equally dramatic increase in the *number* of patents issued (starting in about 1983). For example, the actual number of patents in C&C experienced a *threefold* increase world-wide during 1979-94, whereas the total number of patents increased by just 54 percent.

It is clear that these figures faithfully capture the crucial technological development of the last two decades, namely, the advent of Computers and Communications as the dominant "General Purpose Technology" (GPT) of our era.[11] As to Drugs and Medical, it would seem that its rise is demand driven, following the continuous increase in the share of GDP devoted to healthcare in industrialized nations, and in the United States in particular. Moreover, current developments in Biotechnology may well turn this field into one of the dominant general purpose technologies of the 21st century. General purpose technologies play the role of "engines of growth", and thus their importance goes far beyond their weight as a sector. As the general purpose technology improves and spreads throughout the economy, it prompts complementary advances in user sectors, bringing about generalized productivity gains. A thriving, innovative general purpose technology sector (in this case C&C) is thus a crucial factor dictating the growth potential of advanced economies.

Figure 11 compares the technological composition of all U.S. patents with that of Canadian inventors for the period 1980-94. The picture that emerges is quite disturbing: essentially Canada seems to be "missing the boat" in terms of the prevailing general purpose technology, Computers and Communications, continuing instead to innovate in traditional fields. Thus, the share of C&C patents in Canada barely changed during this period (from 7 to 9 percent), as opposed to a *doubling* of the C&C share for all patents (from the same initial base of 7 percent to 14 percent). It is also worrisome that the share of Electrical and Electronic (E&E), which stood at 18 percent for all patents in 1994, was only 12 percent for Canadian patents. This category embeds both mature E&E fields, but also newer semiconductor technologies, which are important in themselves and also support the C&C sector. Taken together, C&C and E&E accounted for a third of all patents by 1994, whereas in Canada they made just 21 percent.

The flip side of Canada's disadvantage in C&C and in E&E is the high shares of two of the three traditional patent categories: Others, which accounts for almost one third of all Canadian patents (versus 20 percent world-wide), and to a lesser extent Mechanical (the third field, Chemical, is actually lower in Canada that in the rest of the world). In order to look into this matter in more detail, Table 2 shows the top 20 technological sub-categories for Canadian patents granted during 1991-96, and compares their ranking with that of the patents granted to U.S. inventors during the same period.[12]

The most glaring differences are as follows. Canadian inventors patent relatively *much more* (once again, in terms of ranking) than U.S. inventors in the following fields:

- Transportation (rank 3 in Canada, 8 in the United States)
- Furniture and House Fixtures (rank 4 in Canada, 14 in the United States)
- Agriculture, Husbandry and Food (rank 5 in Canada, 15 in the United States)
- Earth Working and Wells (rank 9 in Canada, 18 in the United States)

Canadians patent *much less* than their U.S. counterparts in:

- Computer Hardware and Software (rank 2 in the United States, 15 in Canada)
- Surgery and Medical Instrumentation (rank 3 in the United States, 13 in Canada)
- Resins (rank 6 in the United States, 16 in Canada)
- Power Systems (rank 7 in the United States, 14 in Canada)

FIGURE 11

DISTRIBUTION OF PATENTS BY TECHNOLOGICAL CATEGORIES, 1980-94

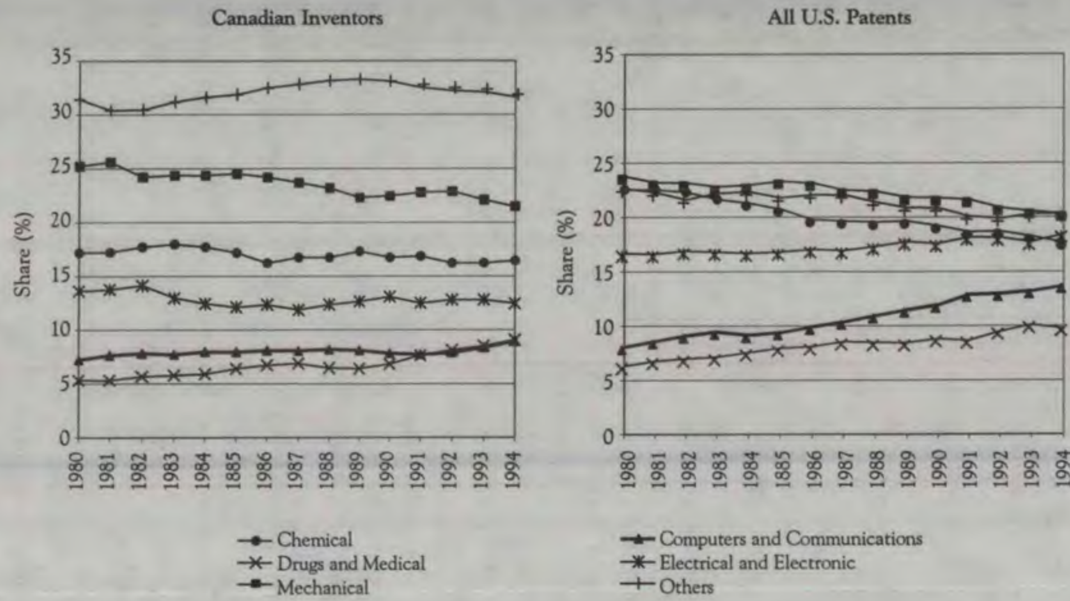


TABLE 2

TOP TECHNOLOGICAL SUB-CATEGORIES*, CANADA VS. UNITED STATES, 1987-96

TECHNOLOGICAL SUB-CATEGORY	NUMBER OF CANADIAN PATENTS	CANADA RANK	U.S. RANK
Mat. Processing and Handling	1,303	1	4
Communications	1,090	2	1
Transportation	796	3	8
Furniture and House Fixtures	745	4	14
Agriculture, Husbandry and Food	719	5	15
Drugs	596	6	5
Metal Working	566	7	11
Measuring and Testing	548	8	9
Earth Working and Wells	528	9	18
Receptacles	525	10	12
Motors, Engines and Parts	498	11	13
Electrical Devices	483	12	10
Surgery and Medical Instrumentation	470	13	3
Power Systems	466	14	7
Computer Hardware and Software	405	15	2
Resins	383	16	6
Liquid Purification or Separation	337	17	26
Amusement Devices	336	18	21
Heating	328	19	27
Apparel and Textile	307	20	25

Note: * Excluding Miscellaneous in each Technological Category.

Thus, the differences in the share of Computers and Communications are due not to Communications (in that sub-category Canadian patents rank almost as high as U.S. patents), but to Computer Hardware and Software, where the disparity is very large.[13] Likewise, the (much smaller) difference in Drugs and Medical is due to Medical Instrumentation, not to Drugs.[14]

WHY IS THE DIVERGENCE IN THE TECHNOLOGICAL COMPOSITION OF CANADIAN PATENTS AN ISSUE?

ONE COULD ARGUE THAT THE TECHNOLOGICAL COMPOSITION of Canadian patents reflects a series of well-grounded economic factors, and hence that its divergence vis-à-vis other countries does not necessarily carry normative implications. That may well be the case, and indeed the top technological sub-categories seem to correlate to some extent with some notion of comparative advantage, relative size of sectors, idiosyncratic technological needs, etc.

The problem is that Computers and Communications (or, more generally, Information Technology [IT]), the area where Canadian patents are lagging the most in relative terms, is not just a field like any other, but as said before it is the dominant general purpose technology (GPT) of our times. Of course, not every country needs to excel technologically in the prevalent GPT in order to benefit from it. Information technologies are spreading rapidly and becoming a powerful economic force all over the industrialized world (and to a lesser degree also in less developed countries), and not just in countries that are innovators in that field. However, in order for an economy to be able to reap the benefits and tap the full potential of a GPT for growth, it *does* need to innovate in it — not so much because the innovations per se are going to impact growth, but because by innovating in the GPT area, a country *develops and enhances its capabilities to harness the GPT for growth.*

The argument here echoes the notion of "absorptive capacity" in the context of basic research (Cohen and Levinthal, 1989). This notion was raised *inter alia* as a response to the puzzle: Why do for-profit firms engage in basic research, given that they cannot appropriate most of the returns from such research? The answer is that in order for those firms to be able to benefit from the basic research done elsewhere (e.g. in academia), they need to engage in such activity themselves. Thus, the scientists working at Xerox's PARC serve *inter alia* as a bridge between world-wide advances in science, and the particular technological needs (or opportunities) at Xerox. The world of IT moves too fast for an economy to be able to adopt a passive stance and still benefit from it. Only those that are in the race themselves can hope to cope with the speed of advances of the leading runners.

It is important to emphasise that the problem lies as said with *Computer Hardware and Software*, not with *Communications*. As we shall see below, this view is reinforced when examining the "quality" of Canadian patents relative to U.S. patents: in Computers there is a big gap in the quality of Canadian patents in favour of U.S. patents, while in Communications the gap is much smaller (Figure 13).

WHO OWNS WHAT? A VIEW AT THE DISTRIBUTION OF CANADIAN PATENTS ASSIGNEES

BY WAY OF INTRODUCTION, we need to describe the different "players" related to any given patent. First there are the inventors, that is, those individuals directly responsible for carrying out the innovation embedded in the patent. Second there is the assignee, that is, the legal entity (corporation, government agency, university, etc.) that owns the patent rights, assigned to it by the inventor(s). However, there are individual inventors that work on their own and have not yet assigned the rights of the patent to a legal entity at the time of issue, in which case the patent is classified as "unassigned".[15] For most patents the inventors are typically employees of a firm, in which case the assignee is the firm itself.

According to the conventions of the U.S. Patent and Trademark Office, the "nationality" of a patent is determined by the address (at the time of application) of the *first inventor*. That is, if a patent has many inventors and they are located in a variety of countries, the location of the first inventor listed on the patent determines to which country it is deemed to belong. Likewise, if the assignee is located in a country different from that of the first inventor, it is once again the location of the latter that determines the nationality of the patent. Notice for example that the patent displayed in Figure 2 is regarded as Canadian even though there is a second inventor that is not, and the assignee is Rolls Royce, GB.[16]

The data that we have presented so far (e.g. number of patents by countries) were compiled according to this convention: Canadian patents are those for which the address of the first inventor was in Canada, regardless of the identity and location of the assignees or of the other inventors, and similarly for the other countries. The important question now is, who actually owns the rights to these inventions? Keeping in mind that for patents labelled "Canadian" it was indeed Canadian scientists and engineers that were responsible for the "innovative act" that led to these patents,[17,18] the question is: which entity, commercial or otherwise, is in a position to reap the economic benefits from these inventions?

At the upper level of aggregation there are three possibilities: (i) that there is no assignee (i.e. the inventor herself retains the rights to the patent), and hence it is not clear if and when the patent will be commercially exploited; (ii) that the assignee is also Canadian, that is, that the location of the entity owning the rights to the patent is in Canada; (iii) that the assignee is foreign. Even the seemingly sharp distinction between (ii) and (iii) is not quite as clear. There are on the one hand Canadian corporations that have established subsidiaries or otherwise related firms in other countries, and they may choose to assign the patents (done is Canada) to their "foreign" subsidiaries (but in fact we should regard them as Canadian). On the other hand, there are multinational corporations that have established subsidiaries in Canada, and some may choose to assign the locally produced patents to the Canadian subsidiary, even though the multinational retains effective control over the property rights.

The distinction between these three categories, unassigned, Canadian ("local") and foreign, is then telling of the extent to which the country can expect to benefit from "its" patents. The unassigned patents may of course find their way to successful commercial applications (and many do), but they typically face much higher uncertainty than corporate assignees that own from the start the patents issued to their employees. Moreover, corporations are in a better position to capture internally the spillovers generated by those innovations. Thus, the higher the percentage of unassigned patents, the lower the economic potential of a given stock of patents. The distinction between foreign and local assignees is presumably informative of the probability that the *local economy* would be the prime beneficiary of the new knowledge embedded in the patent. One can draw various scenarios whereby foreign ownership may be as good if not better in that respect than local ownership of the patent rights (e.g. the foreign multinational offers marketing channels for the innovation that would be inaccessible to local firms). Still, we are rapidly moving in many technological areas to an era where the prime asset is the effective control of intellectual property, and presumably that is correlated with the ownership of patent rights. However, we do not need to take a strong stand in this respect, only to agree that this distinction is informative and quite likely important for understanding the potential value for a country of its stock of patents.

Table 3 shows the distribution between unassigned, "local" and foreign assignees, for Canada, the G-7 and the Reference Group.[19] As we can see, the percentage of local assignees in Canada is much lower than in all other G-7 countries, due primarily to a high proportion of unassigned patents. As to the Reference Group, Finland and South Korea have much higher shares of local assignees than Canada, Israel a slightly higher share, and Taiwan a lower one. Taiwan has indeed a very low percentage of local assignees (due to an extremely high proportion of unassigned — 64 percent!), whereas South Korea has an extremely high share of local assignees (topped only by Japan). These differences are clearly related to the industrial organization of these countries: Taiwan has a very large number of small enterprises, and an extremely high rate of firms turnover, whereas South Korea is dominated by huge, stable *chaebol* (this is a topic worth further investigation). The contrast between the latest figures (for 1998) and those for the period 1976-98 reveal that the G-7 countries are quite stable, whereas the share of local assignees increased in the Reference Group countries, particularly in Taiwan and South Korea.

What characterizes Canada vis-à-vis other countries is that *both* the shares of unassigned and of foreign are relatively high: the percentage of unassigned patents in Canada is the second highest (after Taiwan), and the percentage of foreign is the third highest (after the United Kingdom and Israel). Thus, there is reason for concern in this respect, in that a full half of Canadian inventions may not fully benefit the Canadian economy, either because they are done by individuals that may have a hard time commercializing them, or because they are owned by foreign assignees.

TABLE 3

DISTRIBUTION OF PATENTS BY ASSIGNEE CATEGORIES, INTERNATIONAL COMPARISON, 1976-98

	NUMBER OF PATENTS				PERCENTAGES		
COUNTRY	UNASSIGNED	FOREIGN	LOCAL	TOTAL	UNASSIGNED	FOREIGN	LOCAL*
Canada	15,756	8,614	21,175	45,545	35	19	46 (50)
Other G-7:							
France	6,567	8,883	49,500	64,950	10	14	76 (75)
Germany	13,147	17,060	117,660	147,867	9	12	80 (77)
Italy	3,957	3,904	19,293	27,154	15	14	71 (72)
Japan	9,003	6,950	341,854	357,807	3	2	96 (95)
United Kingdom	5,812	15,698	37,693	59,203	10	27	64 N/A
United States	296,191	19,546	887,308	1,203,045	25	2	74 (76)
Reference Group:							
Israel	1,815	1,807	3,443	7,065	26	26	49 (52)
Finland	834	422	4,739	5,995	14	7	79 (81)
South Korea	1,154	531	10,666	12,351	9	4	86 (92)
Taiwan	13,296	991	6,362	20,649	64	5	31 (44)

Note: * Numbers in parenthesis: percentages for 1998.

THE RELATIVE "IMPORTANCE" OF CANADIAN PATENTS

SIMPLE PATENT COUNTS ARE A VERY IMPERFECT MEASURE of innovative activity, simply because patents vary a great deal in their technological and economic "importance" or "value", and because the distribution of such values is extremely skewed. Recent research has shown that patent citations can effectively play the role of proxies for the "importance" of patents, as well as providing a way of tracing spillovers (Trajtenberg, 1990; and Jaffe, Henderson, and Trajtenberg, 1998). By citations I mean the references to previous patents that appear on the front page of each patent (Figures 1 and 2).

Patent citations serve an important legal function, since they delimit the scope of the property rights awarded by the patent. Thus, if patent 2 cites patent 1, it implies that patent 1 represents a piece of previously existing knowledge upon which patent 2 builds, and over which 2 cannot have a claim. The applicant has a legal duty to disclose any knowledge of the prior art, but the decision regarding which patents to cite ultimately rests with the patent examiner, who is supposed to be an expert in the area and hence able to identify relevant prior art that the applicant misses or conceals.[20]

We use data on patent citations here in order to examine the "quality" of Canadian patents vis-à-vis patents awarded to U.S. inventors. That is, we consider to what extent Canadian patents are more or less frequently cited than U.S. patents, controlling for various effects, and analyze how these differences vary over technological categories. Thus, we regress the number of citations received by each patent on control variables — dummies for 5 technological categories, for grant year (gyear), and for the United States. The sign and magnitude of this latter coefficient is telling the extent to which Canadian patents receive more or less citations on average than U.S. patents, controlling for technological composition and age of patents. The results for the benchmark regression are as follows:[21]

Number of obs.	= 95,473
F(6, 95433)	= 387.46
Prob. > F	= 0.0000
R squared	= 0.1194
Adj. R squared	= 0.1190
Root MSE	= 5.0802

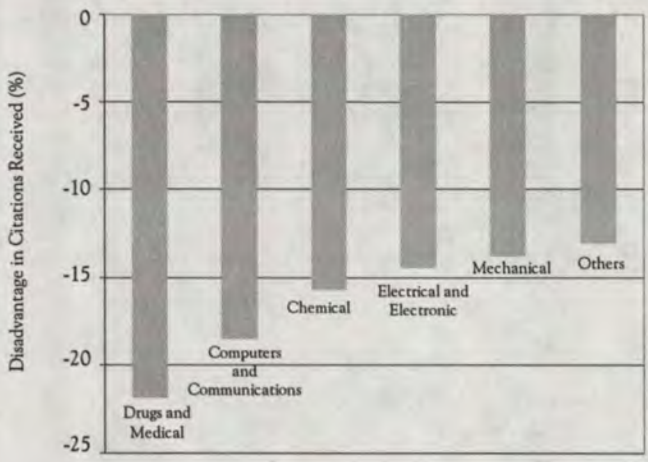
	COEFFICIENT	STD. ERROR	T-STATISTIC
Constant	3.143	0.035	90.496
U.S. Dummy	0.614	0.033	18.403
Dummies for Technological Categories:			
Chemical	0.217	0.049	4.467
Drugs & Medical	2.003	0.077	26.165
Computers & Communications	2.145	0.068	31.376
Mechanical	-0.258	0.045	-5.685
Electrical & Electronic	0.296	0.053	5.605

Note: * gyear F(33,95433) = 337.883 0.000 (34 categories)

Thus, U.S. patents are "better" than Canadian patents by about 20 percent (the coefficient of 0.614 for the United States divided by the constant term of 3.14). Table 4 presents the results of the analysis for each technological category, and Figure 12 shows them graphically. The columns represent, in percentages, the extent to which Canadian patents received lower citation rates than U.S. patents, e.g. in Drugs and Medical the average number of citations received by Canadian patents was 4.41 (Table 4), whereas the average for U.S. patents was 4.4 + 1.2=5.6. Thus, the "disadvantage" of Canadian patents was 4.4/5.6 – 1 = -22 percent. As can be seen in Figure 12, the biggest disadvantage of

FIGURE 12

RELATIVE "IMPORTANCE" OF CANADIAN VS. U.S. PATENTS BY TECHNOLOGICAL CATEGORY



Canadian patents vis-à-vis the United States resides in Drugs and Medical and in Computers and Communications; the smallest is in Mechanical and Others. Once again, this is quite worrisome: the former two are the leading technologies of our time, the latter two are declining traditional fields.

FIGURE 13

RELATIVE IMPORTANCE OF CANADIAN VS. U.S. PATENTS, SELECTED SUB-CATEGORIES

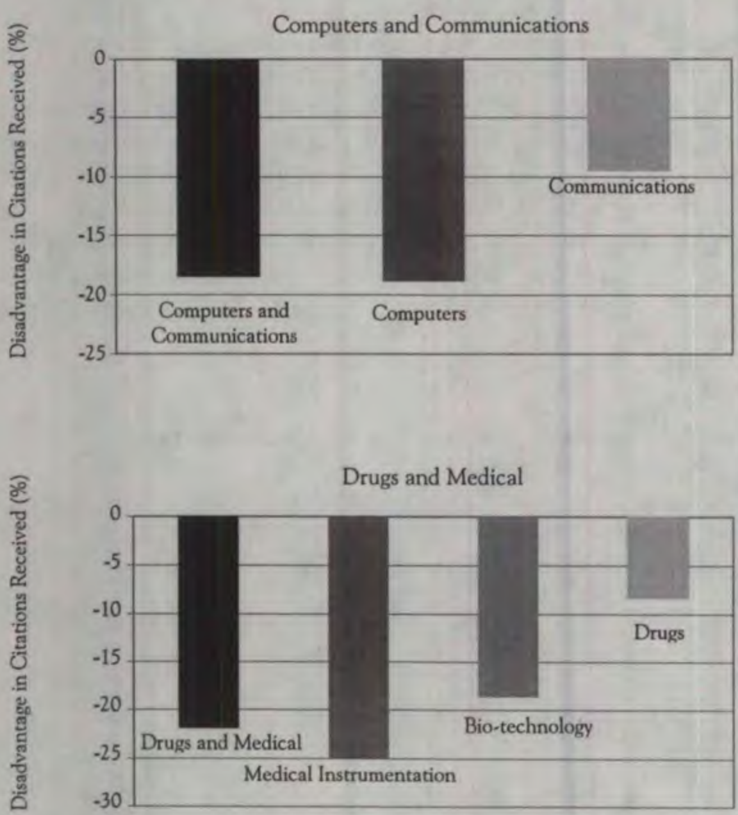


TABLE 4

REGRESSIONS BY TECHNOLOGICAL CATEGORIES

	CHEMICAL	COMPUTERS AND COMMUNICATIONS	DRUGS AND MEDICAL	ELECTRICAL AND ELECTRONIC	MECHANICAL	OTHERS
Constant	3.44	4.75	4.41	3.45	3.02	3.23
	(55.2)	*(37.6)*	*(26.3)*	*(55.1)*	*(79.5)*	*(93.3)*
U.S. Dummy	0.64	1.08	1.24	0.58	0.48	0.49
	(7.7)	*(6.5)*	*(5.6)*	*(7.1)*	*(8.9)*	*(9.6)*
R^2	0.086	0.178	0.139	0.14	0.095	0.123
Number of Observations	18,511	7,020	5,372	14,105	23,353	27,090
Canadian Disadvantage	-15.7%	-18.5%	-21.9%	-14.5%	-13.8%	-13.1%

SUB-CATEGORIES WITHIN COMPUTERS AND COMMUNICATIONS

	COMPUTERS AND COMMUNICATIONS	COMPUTERS	COMMUNICATIONS
Constant	4.75	5.16	4.71
	(37.6)	(19.1)	(35.3)
U.S. Dummy	1.08	1.2	0.49
	(6.5)	(3.7)	(2.6)
R^2	0.178	0.225	0.156
Number of Observations	7,020	2,767	4,253
Canadian Disadvantage	-18.5%	-18.9%	-9.5%

TABLE 4 (CONT'D)

	SUB-CATEGORIES WITHIN DRUGS AND MEDICAL			
	DRUGS AND MEDICAL*	MEDICAL INSTRUMENTATION	DRUGS	BIO-TECHNOLOGY
Constant	4.41	6.08	3.29	2.71
	(26.3)	*(19.4)*	*(13.8)*	*(9.6)*
U.S. Dummy	1.24	2.02	0.3	0.62
	(5.6)	*(5.1)*	*(0.9)*	*(1.6)*
R^2	0.139	0.218	0.082	0.246
Number of Observations	5,372	2,081	2,020	767
Canadian Disadvantage	-21.9%	-25.0%	-8.3%	-18.7%

Notes: * Includes, besides the three sub-categories shown, a "miscellaneous" category.
t-statistics are given in parenthesis.

However, a closer look at Computers and Communications reveals a wide disparity between the two components (Figure 13 and Table 4). In Communications the disadvantage was just -9.5 percent whereas in Computers it stands at -19 percent. That is, Canada suffers from a large gap in the "quality" of patents in *Computers* vis-à-vis the United States, but in *Communications* the disadvantage is much smaller, and in fact it is even lower than in Mechanical and Others, the two traditional fields with the least disadvantage. This is good news, recalling that the rank of patents in Communications (in terms of absolute numbers) is almost as high in Canada as in the United States. That is, Canadian inventors patent a great deal in Communications, and these patents are of relatively high "quality" — still below that of U.S. patents in the same field, but only by a small factor. Thus, the problem that we have identified earlier in terms of the relatively low share of Canadian patents in the dominant GPT of our time, Computers and Communications, is first and foremost a problem in Computers, not in Communications.

Likewise, a detailed examination of the "quality" of patents in Drugs and Medical reveals that the disadvantage of Canadian patents vis-à-vis U.S. patents lies primarily in Medical Instrumentation (Table 4 and Figure 13). In Drugs, the gap with the United States is much smaller (8.3 percent) and not quite significant from a statistical point of view. As said before, Canadian inventors took more patents in Drugs than in Medical Instrumentation (the opposite is true for U.S. inventors), and here again the news are good in that sense.

Concluding Remarks and Policy Implications

Before summing up, it is important to emphasise once again that the foregoing analysis was conducted entirely on the basis of data contained in Canadian and other patents issued by the U.S. Patent and Trademark Office. Clearly, not all Canadian innovations are reflected in those patents (the same is true for the comparison countries), and hence the results should be qualified accordingly. However, there is reason to believe that Canadian patents issued in the United States are indeed representative of the main technological trends and patterns in Canada. That is so both because of the large number of such patents relative to domestic patent applications, and because of fragmentary supporting evidence from other sources on some of the findings (such as the good standing of the field of Communications in Canada).

The picture that emerges from the foregoing analysis is mixed at best, and points at a series of weaknesses in Canadian innovative performance:

1. In terms of relative measures of innovative output such as patents per capita and patents/R&D ratios, Canada stands mid way vis-à-vis the

other G-7 countries, but it has been overtaken in recent years by a group of countries geared towards the high-technology sector (Finland, Israel, Taiwan, with South Korea closing in).

2. Canada stands well below the other G-7 countries (except Italy) in terms of the relative amount of resources devoted to innovation, with a R&D/GDP ratio of 1.5 percent, as opposed to 2.0-2.8 percent for Germany, Japan and the United States.

3. Because of the importance of indivisibilities and critical mass in this area, what ultimately counts is both the absolute amount of R&D, and the absolute number of patents received. Thus, the medium to poor showing in the *relative* measures means a very poor standing in *absolute* terms, and carry potentially serious implications for economic performance.

4. Canadian patenting is highly correlated with lagged R&D spending in Canada as well as with world-wide trends in patenting. The latter are exogenous but the amount of resources devoted to R&D is not. Thus, a current policy shift in favour of R&D spending may boost innovative output in 2-3 years.

5. The "rate of success" of Canadian patent applications in the United States is low relative both to the other G-7 countries and to the Reference Group. It is not clear what accounts for the gap — insufficient selectivity, poor overall "quality" of the applications, procedural difficulties, etc. It is worth examining this area in more detail, since an increase in the success rate may act as a productivity boost to the innovation process.

6. The technological composition of Canadian patents is out of step with the rest of the world: in Canada two of the three traditional fields (Mechanical and Others) still comprise the lion share of patents, whereas the fields of Computers and Communications (C&C) and of Electrical and Electronic (E&E) are well below the world mark.

7. Close examination reveals that the problem lies with Computers (Hardware and Software), and not with Communications. This is true also in terms of the "quality" of Canadian patents in these fields, vis-à-vis U.S. patents.

8. The lagging of Canadian innovation in Computers may have dire consequences for the economic performance of the economy as a whole, since C&C constitutes the leading "General Purpose Technology" of our times.

9. The patterns of ownership of Canadian patents are also troubling: less than half of Canadian patents are owned by Canadian assignees, 35 percent are unassigned (the second highest percentage among the G-7), and 19 percent are owned by foreign assignees. Thus, half of Canadian inventions may not fully benefit the Canadian economy, either because they are done by individuals that may have a hard time commercializing them, or because they are owned by foreign assignees.

10. There is a significant gap of about 20 percent in the "quality" or "importance" of Canadian patents versus patents of U.S. inventors, as measured by the number of citations received. The largest disadvantage was in Drugs and Medical (-22 percent) and in Computers and Communications (-19 percent), whereas in two of the traditional fields Canadian patents exhibited the least disadvantage. A close look reveals that the quality gap resides first and foremost in Computers, not in Communications, and in Medical Instrumentation, not in Drugs.

Clearly, there is a great deal of room for improvement both in the rate and in the direction of innovative activity in Canada. According to most indicators, Canada does possess the human capital and the infrastructure needed to benefit from and innovate successfully in cutting-edge technologies. Whether or not it will do so depends as much on allocative decisions (e.g. R&D spending) as on institutional factors affecting innovation and entrepreneurship. Both are to some extent within the realm of economic policy.

ENDNOTES

1 However, this percentage has been dropping in recent years: it stood at 62 percent in 1978, and dropped to 49 percent in 1992.

2 Rebecca Henderson of MIT also participated in the initial stages of this endeavour, and Bronwyn Hall of Berkeley and Oxford has been involved in it for the past few years.

3 With the assistance of Michael Fogarty and his team at Case Western University.

4 There is a large variance across industries in the reliance on patents versus secrecy: see Levin et al. (1987).

5 There are of course other indicators such as number of scientists and engineers in R&D, business sector R&D, etc. I have chosen real non-defence R&D primarily for reasons of data availability and consistency across countries.

6 I experimented with various lags for R&D (recall that this is non-defence Canadian R&D), and the best fit obtains for a lag of 2 years. However, the results using a 3-year lag are very similar.

7 We chose to normalize the number of patents by population, simply because this is a widely available and accurate statistic that provides a consistent scale factor.

8 The R&D data for the countries in the reference group are spotty and less reliable.

9 Other indicators such as number of researchers per worker (47/10,000 in Canada) provide further evidence to that effect.

10 There is also a slight decline in Chemical patents for non-U.S. inventors — see Appendix B.

11 See Bresnahan and Trajtenberg (1995) and Helpman and Trajtenberg (1998) for a discussion of the notion of "General Purpose Technologies," and an analysis of their implication for growth.

12 The table excludes the "miscellaneous" sub-categories from each of the main categories (i.e. there is a miscellaneous sub-category in Computers and Communications, in Chemical, in Mechanical, etc.).

13 In fact, the number of Canadian patents in Communications was 2.6 times the number in Computers (2,156 versus 816), whereas for U.S. inventors the factor was just 1.3.

14 Canadian inventors took more patents in Drugs than in Medical instrumentation (942 versus 781, with an additional 371 in Biotechnology), whereas the opposite was true for U.S. inventors.

15 In a small number of cases the patent is "assigned to an individual, that is, the inventor herself may appear as the legal entity that owns the patent rights.

16 Clearly, this convention is completely inconsequential for anything but the compilation of statistics about international patenting activity.

17 At least in part, since as said patents classified as "Canadian" may include other inventors located in different countries.

18 The reason we have to be careful with the wording here is as follows: suppose that a Canadian scientist goes to a sabbatical to MIT in Cambridge, MA, and carries out a project in a lab there that results in a patented invention (there are quite a few of these in the data). Such a patent would be labelled as Canadian, but the assignee would be MIT. Now, the invention was made possible not only by the ideas and efforts of the Canadian scientist, but also by the facilities, physical and otherwise, of the host institution. The end result is no doubt a function of both.

19 These figures do not come from the same database as those presented so far: (1) The number of patents assigned to a country in Table 3 includes all patents in which *any* of the inventors resides in that country; (2) the period covered in Table 3 is 1976-98 for granted patents, as opposed to 1968-97 for applied patents in all other tables. Both are due to limitations of the search capabilities in the Internet site of the U.S. Patent and Trademark Office.

20 Because of the role of the examiner and the legal significance of patent citations, there is reason to believe that patent citations are less likely to be contaminated by extraneous motives in the decision of what to cite than other bibliographic data such as citations in the scientific literature. Moreover, bibliometric data are of limited value in tracing the *economic* impact of scientific results, since they are not linked to economic agents or decisions.

21 The data for these regressions consist of all Canadian patents, as well as a sample of 1/50 of patents awarded to U.S. inventors.

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APPENDIX A

ISSUED PATENTS BY APPLICATION YEAR, 1968-97

COUNTRY	1968-72	1973-77	1978-82	1983-87	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Canada	1,106	1,180	1,147	1,345	1,876	2,029	1,938	2,052	1,984	2,274	2,472	2,781	2,564	2,709
France	1,929	2,164	2,199	2,397	2,940	2,925	3,051	2,980	2,926	2,926	3,062	3,449	3,035	3,220
Germany	4,874	5,745	6,167	6,660	7,621	7,759	7,504	6,920	6,966	6,775	7,431	8,180	7,869	8,403
Italy	660	718	819	971	1,267	1,232	1,283	1,250	1,267	1,184	1,268	1,415	1,356	1,393
Japan	4,062	6,385	9,359	13,979	19,866	21,650	22,104	22,811	22,714	22,066	25,352	26,659	25,906	27,386
United Kingdom	2,764	2,709	2,357	2,429	2,704	2,811	2,594	2,341	2,265	2,474	2,819	3,086	2,743	2,946
United States	45,150	41,894	38,222	37,990	46,968	50,190	53,266	53,790	56,690	59,264	65,384	74,610	64,947	73,182
Finland	70	103	143	212	262	310	350	352	329	361	460	503	544	580
Israel	58	102	137	211	281	318	325	316	355	422	578	605	566	650
South Korea	4	9	20	74	205	409	510	795	906	1,026	1,587	2,029	2,851	3,302
Taiwan	1	33	87	279	557	725	932	1,116	1,260	1,567	1,908	2,197	2,688	3,097

Sources of Data on Yearly Patent Counts by Countries.

The difficulty in obtaining accurate patent counts by *application year* stems from the lag between application and grant, which causes truncation in the figures for recent years. That is, we have the complete figures for patents by grant year up to 1998, but not by application year. However, one can estimate these figures relying on the previous percentage of "successful" applications (since we do have the number of raw applications for recent years) and other data. In particular, the figures showed in Appendix A (and used throughout the paper) were compiled and/or estimated as follows:

Up to 1989: from our data file.

For 1990-94: taken from the latest TAF-USPTO report as given there. These figures are based upon patents granted up to the end of 1998, but since over 99 percent of patents are examined by the forth year after application, these figures may be regarded as essentially complete.

For 1995: (patents applied in 1995 and granted up to 1998)/(ratio of 1995 patents whose examination was completed by 1998=0.98).

For 1996: average of the following two estimates: (*i*) (patents applied in 1996 and granted up to 1998)/(ratio of 1996 patents whose examination was completed by 1998=0.84); (*ii*) (number of raw applications in 1996)*("national success ratio": percentage of patents applied for in 1994 and 1995 that were eventually granted, out of raw applications in those years).

For 1997: (number of patent applications filed in 1997)*(estimated national success ratio for 1996). The later was computed as: (estimated number of patents granted in 1996)/(number of applications in 1996).

APPENDIX B

TOTAL NON-DEFENSE R&D EXPENDITURES IN G-7 COUNTRIES (CONSTANT 1992$ BILLIONS)

COUNTRY	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Canada	5.15	5.56	5.61	6.11	6.62	6.99	7.02	7.14	7.31	7.75	7.90	8.21	8.68	9.00	9.13
France	13.38	14.46	15.24	16.14	16.87	16.97	17.51	18.32	19.70	20.48	21.15	22.42	22.03	21.73	21.72
Germany	22.95	23.69	24.05	24.70	27.07	27.96	29.92	31.03	32.37	32.58	35.04	35.84	34.45	34.35	34.22
Italy	6.77	7.06	7.45	8.01	9.09	9.44	10.31	10.80	11.38	12.38	12.74	13.13	11.90	11.30	11.54
Japan	34.83	37.38	40.31	43.25	48.00	48.76	52.07	56.20	61.55	66.58	67.94	68.91	66.55	65.63	69.74
United Kingdom	13.66	13.39	13.12	13.84	14.56	15.65	16.18	17.13	17.61	17.97	16.57	17.83	17.80	17.99	17.17
United States	81.41	82.55	86.25	93.88	100.36	101.90	103.34	107.79	113.79	120.92	127.83	129.36	126.28	128.58	138.35

Data taken from NSF site, "National Patterns of R&D Resources: 1998 Data Update" (table b8.xls).
Canada figures for 1992 and 1994 were calculated from total R&D in Canada for that year by taking the average ratio of previous and next years ratio of non-defence R&D to total R&D.
For the United Kingdom in 1982 and 1984 we took the average of previous and next year non-defence R&D.
For France in 1995 we took the non-defence R&D to total R&D ratio of the previous year.

APPENDIX C

FIGURE C1

DISTRIBUTION OF PATENTS BY TECHNOLOGY CATEGORIES, U.S. INVENTORS

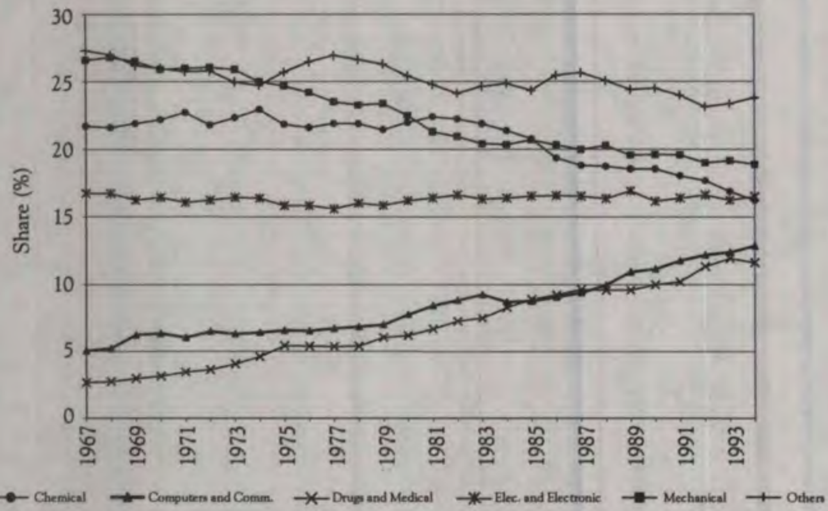
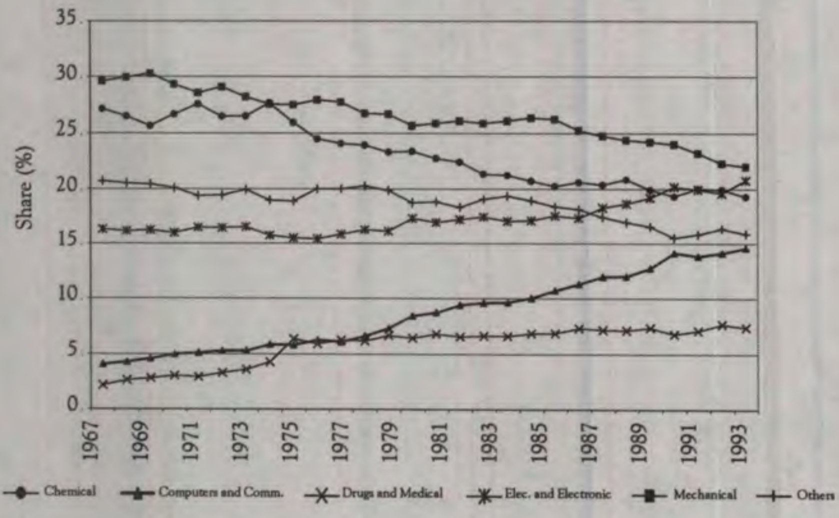


FIGURE C2

DISTRIBUTION OF PATENTS BY TECHNOLOGY CATEGORIES, NON U.S. INVENTORS



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9

Linkages Between Technological Change and Productivity Growth

INTRODUCTION

THE PURPOSE OF THIS STUDY is to review and synthesize the relevant literature dealing with the linkages between technological change and productivity change. The two concepts, although theoretically distinct, are often linked in policy discussions, and both are the focus of a wide range of public policies.

Recent commentaries in the popular press have highlighted Canada's stagnating productivity performance relative to that of the United States.[1] Various possible explanations have been suggested including a long-standing concern in Canada about the relatively small amount of research and development (R&D) carried out by firms in this country.[2] Indeed, a number of other possible explanations including government regulations and the decline in the value of the Canadian dollar, which raises the cost for Canadian companies to import productivity-enhancing technology, are also linked to technological change.[3]

A slowdown in the rate of technological change has also been widely bruited as a possible cause of the post-1973 productivity growth slowdown among developed countries. While the evidence (reviewed below) on this issue is inconclusive, there is now a growing perception that major technological developments in computing and telecommunications, including the emergence and growth of the Internet as a major new mode of mass communications, will induce a new and dramatic improvement in productivity growth, as well as in the growth of real incomes.[4]

The propensity of policymakers to look to the promotion of technological activities as an important component of industrial growth strategies is certainly not new, especially in Canada where a debate about the causes and consequences of technological change has taken place over at least three decades.[5] Having implemented one of the most generous R&D tax regimes among OECD countries, the apparent failure of Canadian productivity growth rates to track those of other countries is disappointing. It is also a cause for questioning the faith being reinvested by the Canadian government in offering yet more financial assistance for technological activities.

The linkages between technological activities and productivity changes are complex and difficult to measure. Thus, notwithstanding the relatively large literature on the topic, there is no 'conventional wisdom' on either the nature or the magnitude of these linkages. The purposes of this chapter are to review and synthesize the relevant literature, as well as to highlight important areas for future research and suggest specific research projects.

The report proceeds in the following way. The first section *Technological Change and Productivity Change* sets out the simple theoretical linkages between productivity growth and technological change. It also identifies and evaluates the conceptual and empirical problems associated with specifying and estimating those linkages. The next section *Empirical Studies of R&D, Innovation and Productivity Growth* summarizes and synthesizes empirical studies of the relationships between R&D, innovation and productivity at the levels of both the aggregate economy and individual industries and firms, or groups of industries and firms. The section entitled *Factors Conditioning the Innovation-productivity Growth Linkages* discusses factors that have been identified as 'conditioning' the empirical relationship between technological change and productivity change, including the educational level of the workforce, industrial competition and so forth. The section entitled *Temporal Patterns in the Linkages* looks at whether there is any temporal pattern in the observed linkages between technological change and productivity change and what factors might account for any observed pattern. The entitled *Computerization and Productivity Growth* focuses on the relationship between computerization and related technological changes in telecommunications and productivity change. The main issue of interest here is whether the 'digital revolution' is sparking an accelerated growth in productivity and, if not, why. The next section, *Agreements, Disagreements and Uncertainties*, identifies the important remaining gaps in our knowledge about the relationship between technological change and productivity change. The section entitled *Future Research Agenda* suggests a number of research projects designed to address the gaps identified in the preceding section.

TECHNOLOGICAL CHANGE AND PRODUCTIVITY CHANGE

WHILE TECHNOLOGICAL CHANGE is sometimes identified synonymously with productivity change, the two are distinct, albeit related concepts. Specifically, technological change is a contributor (of greater or lesser importance) to productivity change. Identification of the contribution of technological change to productivity change, in turn, requires some precision in the measurement of the latter.

PRODUCTIVITY MEASURES

PRODUCTIVITY MEASURES ENCOMPASS INDEXES for individual factors of production, e.g. labour or capital, and indexes for a weighted average of individual factors of production. Productivity measures for individual factor inputs are known as partial factor productivity indices. Productivity measures encompassing all input factors are known as total factor productivity indices. Hence, labour productivity is an index of a series of real output divided by a series of real labour input. The most common index of labour productivity is real output per hour worked. Similarly, capital productivity is an index of a real output series divided by a real capital input series. In fact, output per labour hour is the most widely available productivity measure for international comparisons, as well as inter-industry comparisons.[6]

Multi-factor or total factor productivity (TFP) is constructed as the ratio of real output (or real value added) to a weighted average of inputs, where the weights are the relative importance of each factor in the cost of production. TFP indices are constructed for both gross and net output (value added), where gross output includes intermediate material inputs and net output excludes such inputs.[7] International comparisons most frequently report the ratio of real output to a weighted average of labour and capital inputs.

The growth in the calculated partial or total factor productivity over time is, therefore, a measure of the growth of productivity. When the index is expressed as a rate of change, one obtains an estimated productivity growth rate. Table 1 reports labour productivity growth estimates for a sample of Canadian industries. The main observation worth highlighting is the relatively sharp decline in the rate of productivity growth, post-1973, in all of the sample industries. In most cases, productivity growth continued to decrease throughout the 1980s and 1990s, albeit at a slower pace than in the immediate post-1973 period. This pattern is essentially mirrored in other developed economies. Explanations of productivity performance must therefore be consistent with this striking and ubiquitous observation.

The causes of observed changes in productivity performance will be conditioned, in part, by the way in which productivity is measured. For example, in the case of partial productivity measures, productivity growth rates or levels can be higher in one country (or one industry) than another either because the two use different combinations of factor inputs, or because one uses a factor input more efficiently than the other. An obvious illustration is provided in the case of the labour productivity measure. Labour productivity will ordinarily increase as capital is substituted for labour due to the diminishing marginal

TABLE 1

LABOUR PRODUCTIVITY

INDUSTRY	ANNUAL RATE OF GROWTH 1963-73	1973-92
Agriculture, Forestry and Fishery	4.96	2.85
Mining and Quarrying	5.37	0.91
Food, Beverage and Tobacco	3.23	1.58
Textile, Apparel and Leather	4.46	2.40
Wood Products and Furniture	3.29	2.51
Paper, Paper Products and Printing	3.10	1.22
Chemicals	4.26	0.75
Non-metallic Mineral Products	3.88	0.68
Basic Metal Products	2.88	2.33
Metal Products	3.44	0.93
Agricultural and Industrial Machinery	3.95	3.41
Electrical Goods	4.09	3.83
Transportation Equipment	5.95	1.99
Other Manufacturing Equipment	4.01	0.46
Electricity, Gas and Water	5.16	1.41
Construction	2.48	1.23
Wholesale and Retail Trade	2.17	1.29
Restaurants and Hotels	1.26	-0.55
Transport and Storage	5.47	1.89
Communications	6.03	5.69
FIRE and Business Services	1.70	1.21
Community and Personal Services	1.03	0.52

Note: Labour productivity is measured by gross output per hour worked.
Source: Gera, Gu and Lee (1998b).

productivity of variable inputs. Hence, labour productivity will ordinarily be higher in more capital-intensive economies, industries and firms, all other things constant. At the same time, labour productivity might be higher in specific economies or organizations because labour is used more efficiently holding the input of capital constant.

The use of TFP measures mitigates the impact of factor substitution on measured productivity performance and, hence, isolates the consequences of 'pure' efficiency gains more precisely. Nevertheless, there are complications shared by both partial and multi-factor productivity measures that can potentially give rise to misleading or inappropriate conclusions about the behaviour of productivity. For example, productivity measures should, in principle, account for both the quantity and quality of output(s) and input(s); however, incorporating quality changes meaningfully into output and input series presents a very difficult challenge.[8]

Another complication is the emergence of new outputs over time. To the extent that price indices used to deflate monetary measures of outputs and inputs to their real values are based upon baskets of outputs that are not perfectly representative of the actual mix of outputs purchased, price indices (and real output measures) will be biased. This implies biases in the calculated productivity indices.

Divergences between the output weights used to develop price indices and actual output weights are virtually certain to occur as statistical agencies such as Statistics Canada and the Bureau of Labor Statistics use a defined basket of goods as output weights for a discrete period of time. An implication is that measured productivity is unlikely to be an accurate measure of 'true' productivity at any point in time. Moreover, if factors contributing to measurement errors vary in importance over time, even the temporal performance of measured productivity can be an inaccurate guide to true productivity trends.[9]

Technological Change

In its broadest sense, technological change can be thought of as the rate at which new production processes and products are introduced and adopted in the economy. The former is traditionally identified as the innovation stage, while the latter is identified as the diffusion stage. Most observers contend that any distinction between the innovation and diffusion stages of technological change is arbitrary, since diffusion involves continuous adaptation and improvement of the initial innovation. The introduction and adoption of new production processes and products presumably enable society to enjoy higher levels of real output holding constant the services of traditional inputs such as labour and capital. Hence, it should lead to increased productivity. Similarly, a faster rate of growth of technological change should lead to a faster rates of productivity growth, all other things constant. In this context, technological change is not necessarily a 'free lunch.' That is, real resources must be expended to encourage technological change. However, the presumed net result is still increased real output given any initial endowment of factor inputs.[10]

New production processes often require the introduction and adoption of new products, e.g. new capital equipment, in order to be used. Hence, there is often no clear dividing line between a new process and a new product. Nevertheless, economists tend to think of new processes as primarily leading to reductions in conventional costs of production, whereas new products primarily lead to direct increases in the welfare of consumers by offering either new attributes or greater 'conventional' attributes for the same price as older products (or a lower price).[11] While there is no implication that one form of technological change is more desirable, cost-reducing innovations are often more readily identifiable than 'quality' improvements to existing products.

As noted above, technological change leads to increased productivity by increasing the real output (or, equivalently, the real income) of society that is attainable with the available productive resources. It might be noted that meaningful increases in real income also arise from reductions in 'undesirable' outputs in the economy, such as pollution, crime and disease. Hence, technological change does not have to be associated with increases in material wealth in order to improve productivity.

The conceptual and practical problems associated with measuring technological change are, if anything, even more severe than those associated with measuring productivity change. Indeed, it is difficult to conceive of a single measure that would accurately reflect the complex and heterogeneous nature of technological change. As a result, various proxy measures are used by economists.

R&D as a Proxy for Technological Change

Perhaps the most widely used proxy for technological change is research and development (R&D) expenditures.[12] The straightforward presumption is that R&D is a necessary, albeit not sufficient, prerequisite for technological change. While there is much direct and indirect support for this presumption, it is much less clear that there is a precise and consistent relationship between R&D and technological change. For example, it is sometimes argued that the linkage between R&D and technological change is stronger during specific historical periods than others. Thus, it has been argued that the basic science 'available' to be exploited by commercially oriented R&D was more abundant at various times prior to the mid-1900s, which is partially why rates of technological change (and productivity change) slowed during the post-1973 period.

It has also been argued that the nature of the R&D activities undertaken will condition the latter's linkage to technological change. For example, while it is conventionally assumed that R&D carried out in the private sector has a larger direct impact on productivity than R&D carried out in government or university laboratories, the indirect impact of non-profit R&D, especially basic research, can be quite large. Specifically, research carried out by non-profit organizations can be complementary to the R&D carried out by for-profit concerns. This leads to the possibility that both the mix and the quantity of R&D carried out in society influence subsequent rates of productivity change.[13] The evidence relating the composition of R&D to productivity and real economic growth will be reviewed in a later section.

The measurement of the stock of R&D capital, as an approximation of the stock of technical knowledge, is also subject to some of the problems that plague the accurate measurement of productivity growth. Two particular challenges complicate the construction of R&D capital stock measures: 1) deciding upon the appropriate depreciation rate for historical R&D expenditures,[14] and 2) determining the 'correct' weight for R&D conducted outside the firm (or industry, or nation) to combine this potential source of borrowed or acquired technical knowledge with 'own' R&D expenditures.[15]

Notwithstanding these measurement problems, R&D measures continue to be the most widely used proxies for technological change.

Patents and Other Proxies

Patents are prominent among other proxy measures of technological change. Whereas R&D expenditures are input-based proxies, patents are presumably output-based proxies. All other things constant, output-based proxies should be more meaningful than input-based proxies. Nevertheless, there are a number of well-known shortcomings associated with using patent intensities as measures of technological change. One is that patents may not be needed for technological activities where trade secrecy is a robust means of protecting intellectual property. A second is that simple patent counts are not necessarily indicative of the commercial significance of the underlying technology, or of the productivity impact of the underlying technology, all else constant. Indeed, patenting in some circumstances may be motivated primarily by a desire to increase the costs of entry facing potential rivals, in which case the major direct outcome of patenting activity is to generate monopoly profits rather than real productivity improvements. These caveats suggest caution in linking productivity change to patenting activity in order to assess the linkages between technological change and productivity change.[16]

In other cases, statistical or case studies focus on specific innovations and link the introduction and adoption of those innovations to the productivity performance of an industry.[17] The focus on specific innovations and their utilization allows a more detailed evaluation of the rich set of background factors that ordinarily condition managerial decisions to implement new technology, as well as the consequences of creating and implementing new technology. On the other hand, such focus limits the extent to which the findings can be generalized. Also, many innovations cannot be easily identified or segmented for purposes of specific study. For example, it is often difficult to identify organizational changes that may, in turn, affect productivity, or else specific changes are linked to other ongoing changes so that one is trying to attribute individual effects to what is really a set of joint 'technological' inputs.

Technological Spillovers

Any measure of technological change needs to acknowledge that technological change going on outside the unit of analysis, whether that unit is an individual firm, an industry or a country, will affect the linkages between technological change and productivity change within the unit. Indeed, technological change occurring outside the unit can affect technological activities within the unit by altering the relevant marginal products and marginal costs of those activities.

The relevant concept here is technology spillover, which may be thought of as new technology created by specific organizations that is appropriated by other organizations without compensating (fully or at all) the creators for the value of the technology appropriated. An implication is that the productivity impacts of technological change may extend over a much broader range of organizations than those performing the bulk of the R&D, patenting and related activities associated with the technology in question. A related implication is that observing individual (or groups of) organizations performing relatively small amounts of R&D or patenting activity does not necessarily suggest that technological change is unimportant to ongoing productivity change in those organizations. Rather, it might suggest that conventional measures of technological activity are poor proxies for the actual stock of technological knowledge available to these organizations.

There is a substantial literature examining the technology spillover process, as well as the factors conditioning the magnitude of those spillovers. This literature will be briefly reviewed in a later section. At this point, it is worth noting that the spillover phenomenon is of special potential relevance to Canada. In particular, the presence of relatively high degrees of foreign ownership has been linked to relatively low R&D intensity levels in Canadian manufacturing industries. The latter, in turn, has been linked to Canada's 'poor' record in industrial innovation and productivity growth by those who believe that tighter controls on foreign ownership are in Canada's economic interest. On the other hand, proponents of a liberal foreign ownership regime argue that foreign-owned companies are a robust source for importing technology into Canada and therefore reduce the need for Canadian companies to undertake costly indigenous R&D.[18] Evaluation of these two competing positions requires evidence on the magnitude of the returns to indigenous versus 'spillover' technology, as well as an assessment of the impacts of foreign ownership on each.

Technology Embodied in Labour and Capital

> The introduction of new methods of production is so completely intertwined with capital investment that a monumental estimation problem presents itself to those who wish to measure the various influences of capital investment on productivity.
> (Boucher 1981, p. 94)

To the extent that new technology is embodied in labour and capital inputs, a potential identification problem arises. Specifically, it becomes difficult to identify empirically the contribution of 'conventional' factor inputs to productivity growth separately from the contribution of new technical knowledge. Some economists have argued that the greatest portion of technological change takes the form of improved inputs, especially capital inputs. To the extent that this is true, increased usage rates of newer inputs will contribute to productivity growth, and it may be difficult to separate the impact of using improved inputs from that of an increased use of inputs, *per se*. A similar consideration applies to situations in which technological change is accompanied by increases in the scale of organizations and industries. That is, it can be difficult to empirically separate the productivity effects of increases in the scale and scope of economic organizations from the effects of implementing and exploiting new technologies, holding scale and scope constant.

Exogenous and Endogenous Technological Change

Complexities in modelling and estimating the linkages between productivity growth and technological change are exacerbated by the potential for direct and indirect simultaneity between the two processes. For example, a disembodied technological change, such as mathematical research that facilitates the implementation of high-speed digital communications networks, may ultimately spur investment in new computers and communications equipment that, in turn, introduces new technology into a wide range of manufacturing and service-sector activities. Productivity improvements resulting from the investment in new computer and communications equipment therefore reflect both the underlying mathematical research, as well as new capital investment. Separating the contributions of each to productivity growth is obviously a difficult empirical task.

EMPIRICAL STUDIES OF R&D, INNOVATION AND PRODUCTIVITY GROWTH

> Inventions and innovations have been a major source of technological improvements and productivity gains.
> (Fortin and Helpman 1995, p. 17)

NOTWITHSTANDING THE WIDELY ACKNOWLEDGED DIFFICULTIES in identifying the linkages between technological change and productivity growth, there is a vast empirical literature on the subject. Indeed, the size and scope of the relevant literature are far too extensive to summarize thoroughly in this report. Rather, reliance is placed upon reviewing other, fairly comprehensive, summary reviews of the literature along with relatively recent studies that significantly reinforce or amend earlier findings.[19]

There have been two broad approaches to identifying the contribution of technological change to productivity growth. One involves econometric and non-econometric identification of residual TFP growth after all factors potentially contributing to TFP growth (other than technological change) have been identified. This approach is associated with economists such as Edward Denison and Dale Jorgenson.[20] While these studies tend to document the statistical importance of the 'unexplained' productivity residual (presumed to be technological change), there is substantial controversy surrounding the interpretation of the residual. In particular, there has been substantial debate surrounding the degree to which the residual reflects biases in the measurement of 'conventional' physical capital and other inputs, as well as the contribution of economies of scale related to new production techniques.

A second approach, which is more representative of recent research seeking to identify linkages between technological change and productivity change, incorporates measures of technological change as explicit variables in models of productivity growth. The bulk of these studies focus on R&D performance as the proxy measure of technology; however, some case studies look at specific innovations and their economic effects. Our review of the relevant literature focuses on this second set of studies.

The literature review in this section will give separate consideration to econometric and non-econometric evidence. The primary focus of the review will be to identify and synthesize reported findings with respect to the following issues: 1) the private and social rates of return to R&D and other measures of innovation and technological change; 2) the private and social rates of return to different types of R&D and innovation, e.g. basic versus applied; government-funded versus privately funded; undertaken by for-profit or not-for-profit (including academic) organizations; and 3) the sources of technology spillovers, e.g. foreign R&D versus domestic R&D.

A second focus of the review is to summarize the specific available findings on these issues for Canada and to identify and explain, if possible, any distinctive differences between the Canadian and non-Canadian experiences.

Econometric Studies

These studies encompass statistical analyses of the linkages between real output (or productivity) measures and factors determining output (or productivity) changes including measures of technological change. The typical 'setup' in these studies is to express the real growth of (or differences in) output as a function of the real growth of (or differences in) 'conventional' factor inputs including labour and capital, and non-conventional inputs such as the services of R&D capital. Within a Cobb-Douglas (or a more flexible) production function framework, we can get direct estimates of output elasticities. In related models, the real output equation is transformed into a productivity specification. For example, labour productivity may be expressed as the difference in the growth rates of real output and real labour input. In models where the dependent variable is a measure of productivity, the estimated coefficients of the 'technological change' variables are rates of return to technology inputs such as R&D.[21] The constant term is interpreted as a measure of the rate of disembodied technological change — that is, productivity growth unrelated to the growth in explicit technology input variables.

Canadian Evidence

BERNSTEIN (1988) PROVIDES ECONOMETRIC EVIDENCE on private and social returns to R&D in Canada for a set of industries. He identifies the relative and absolute importance of spillovers through the fact that social rates of return to R&D investment are substantially higher than private rates of return. In fact, inter-industry spillovers are relatively small for all of the sample industries. Conversely, intra-industry spillovers are relatively large, particularly in industries that have a relatively large R&D spending propensity.[22]

The orders of magnitude are as follows: the social rates of return to R&D capital (net of depreciation) in industries with a larger R&D spending propensity are slightly more than double the 11.5 percent net private rate of return. Social rates of return to R&D capital in other industries are somewhat less than double the net private rate of return.

Bernstein also provides some evidence on the relationship between R&D spillovers and R&D performance in his sample. Specifically, inter-industry spillovers act as a substitute for the R&D capital input of the firm itself in every sample industry. The effect is quite pronounced, especially in industries with a relatively low propensity to spend on R&D capital. The intra-industry spillover effect on the performance of 'own' R&D is smaller in absolute value than the inter-industry spillover effect. In industries with a relatively low R&D propensity, R&D spillovers discourage the performance of own R&D. In industries with a relatively high R&D propensity, there is a complementary relationship between intra-industry spillovers and own R&D performance.

Bernstein does not identify the specific channels through which spillovers occur, and he mentions this as an important focus for extending his work. It is perhaps suggestive that in the five industries where there is a significant difference between Canadian and foreign-owned firms' response to intra-industry spillovers, the unit costs of foreign-owned firms decrease relatively more than those of their Canadian counterparts. This result suggests that foreign direct investment may be an especially robust channel for intra-industry technology spillovers.

In a related study, Bernstein (1989) identifies the R&D spillovers from one Canadian industry to another. Nine separate manufacturing industries are examined for the period 1963-83. He finds substantial variation across receiving countries with respect to the number of industries generating spillovers. As well, spillover elasticities for the receiving countries were significantly different from each other. All nine industries had consistently high private returns to R&D. This latter result is not supported by a number of other Canadian studies. However, Bernstein's finding that social rates of return substantially exceed private rates of return is consistent with other studies. Industries with a relatively high R&D intensity did not necessarily have a higher rate of return on R&D capital. Nor were they consistently the major sources of R&D spillovers.

In a more recent study, Bernstein (1996) focuses on technological spillovers associated with R&D activity in the communications equipment industry. He finds substantial spillovers from this industry to the entire Canadian manufacturing sector. In terms of relative importance, however, the R&D spillovers from the U.S. manufacturing sector have a greater impact on Canadian manufacturing factor intensities than spillovers from the domestic communications equipment industry. At the same time, there are spillovers from both the Canadian manufacturing sector and the U.S. electrical products industry to the Canadian communications equipment industry. The R&D capital from the U.S. electrical products industry has a greater impact on the production structure of the Canadian communications equipment industry than R&D capital from the Canadian manufacturing sector.

Bernstein's study of the communications equipment industry further underscores the importance of international technology spillovers to Canadian industries. Specifically, he finds that spillovers from the U.S. manufacturing sector accounted for around three-quarters of the average annual rate of productivity growth in all Canadian manufacturing industries. The important spillovers from the Canadian communications equipment industry are underscored by the differences between the private and social rates of return to R&D in that industry. Specifically, the social rate of return to Canadian communications equipment R&D capital is estimated at 55 percent, or 225 percent higher than the private rate of return. By contrast, the social rate of return associated with Canadian manufacturing R&D capital is estimated at 21, or 24 percent higher than the private rate of return. The implied negative private rate of return to manufacturing R&D capital is consistent with a number of other studies that fail to identify any within-industry productivity effects of private R&D expenditures in Canadian manufacturing industries. This latter result is a curiosity that remains to be explained satisfactorily.

Mohnen (1992) reviews a number of Canadian and non-Canadian studies of the returns to R&D and presents some original econometric evidence. He notes in his review that there is mixed evidence for Canada. Specifically, a number of studies offer little support to the existence of a strong link between R&D and TFP growth; however, others obtain estimates that are consistent with those found for other countries. His own econometric results suggest a weak linkage between Canadian R&D and TFP growth in Canadian industries.[23] Indeed, in some specifications of the model, there is no statistically significant relationship. He suggests that the issue be re-addressed with new data and new models. In particular, a more disaggregated analysis might provide a clearer picture of why the impact of R&D performed in Canada differs from that of R&D performed elsewhere.

With respect to other characteristics of R&D, Mohnen tends to confirm the conventional wisdom. In particular, social returns to R&D are substantially higher than private returns, and returns are higher on company-financed R&D than on publicly financed R&D. The latter result underscores the indirect contribution of publicly financed R&D, i.e. it is a complement to privately financed R&D.

The previously cited findings of relatively low private rates of return to R&D expenditures by Canadian manufacturing firms seemingly belie the wisdom of frequent calls for increased government encouragement of private R&D expenditures. Indeed, they may suggest that Canada's relatively generous framework of support for private sector R&D encourages a substantial number of marginally profitable innovation activities. Alternatively, they may suggest that the environment for exploiting industrial scientific breakthroughs in Canada is unfavourable, and that the breakthroughs, such as occur, are exploited by the user companies in ways that do not directly improve the productivity of Canadian manufacturing establishments. For example, new industrial knowledge might be used primarily by the foreign affiliates of Canadian multinational companies.[24] Given the paucity of evidence bearing upon this issue, it is impossible to do more than speculate on the plausibility of both the reported findings on private returns to Canadian industrial R&D, and the explanations of those findings.

Other Studies

Griliches (1998) summarizes the results of extensive econometric studies of rates of return to privately and publicly funded R&D in the United States. These returns tend to cluster in the range of 18 to 20 percent. He highlights the fact that there is no differential impact of federal versus private company

R&D dollars on the levels and rates of growth of total factor productivity at the firm level, although differences are evident at the industry level. It is suggested that the latter result reflects the differential rates of government R&D funding across industries. To the extent that government funding is concentrated in areas where private funding would otherwise be excessively low from the perspective of social efficiency, perhaps because the returns to R&D are particularly difficult to appropriate in those areas, differences between returns to privately and publicly funded R&D should be expected. The studies almost uniformly show substantial and significant returns to own R&D.[25] Significant spillovers from R&D conducted outside the firm are also documented.[26]

The difficulty with identifying returns to own R&D and R&D conducted outside the organization is that own R&D may enable the organization to better exploit available R&D spillovers. Studies tend to show that the interaction between a firm's R&D stock and foreign R&D spillovers is generally positive and significant.[27] This result is consistent with findings that foreign technology spillovers are a complement to the firm's own R&D. This complementarity was noted earlier in Canadian studies referenced. What is less well established in the literature is how the nature of internally performed R&D affects the ability of an organization to benefit from technology spillovers. For example, is applied research more complementary to technology spillovers than expenditures on process and product development? The issue seems especially relevant for Canada, given the prominent contribution that foreign technology spillovers make to productivity growth in this country.

Available evidence suggests that returns to R&D vary with the nature of the R&D undertaken. For example, the rate of return to basic research is higher than the rate of return to R&D expenditures, on average (Griliches 1998).

Case Studies

Case studies of specific innovations provide another approach to examining the social and private returns to innovation. Such case studies are subject to the familiar criticism that their results cannot necessarily be generalized. However, they tend to be consistent with the outcomes of econometric studies. Hence, in combination with econometric studies, case studies tend to paint a fairly consistent picture of the impacts of innovative activities.

Mansfield (1996) summarizes a number of major case studies of industrial innovations including some of his own work. The innovations identified primarily took place in manufacturing industries, albeit covering a wide range of manufacturing activities. Many of the innovations studied were of average importance, so as to avoid the obvious bias of focusing on particularly successful innovations. While social rates of return vary across innovations, they are typically quite high, i.e. generally in the range of 30 to 50 percent, and sometimes much higher. Typically, these estimated social rates of return are substantially higher than the corresponding private rates of return, and the gap is especially pronounced for major innovations.

Baily and Chakrabarti (1988) examine four industries (chemicals, machine tools, electrical power and textiles) quite intensively. Based upon case studies, they argue that the evolution of technology has been a vital part of the productivity performance of these industries.

Griliches (1998) summarizes several other case studies, particularly those focused on government-supported innovative activities. These studies also confirm the existence of very high rates of return to innovation. For example, the rate of return to R&D expenditures by NASA is about 40 percent per year in perpetuity. This is more than double the rate of return to all other types of R&D undertaken in the United States. However, Griliches offers a number of strong methodological criticisms of these studies.

Existing research tends to conclude that publicly financed R&D has a lower rate of return that privately financed R&D. In part, this reflects the non-commercial nature of much of the R&D financed and undertaken by governments. However, government-financed R&D, on average, generates spillovers for private R&D endeavours. Specifically, it reduces the cost to industries and thus enhances their productivity growth. However, it also seems that publicly financed R&D crowds-out company-financed R&D in many industries (Mamuneas and Nadiri 1996).

Patent data indirectly support the conclusion that technological activity undertaken in government and university laboratories leads to significant scientific benefits. For example, Henderson, Jaffe and Trajtenberg (1998) examine a comprehensive database consisting of all U.S. patents granted to universities or related institutions from 1965 until mid-1992. They show that, averaged over the whole period, university patents are both more important and more general than the average patent, but that this difference has been declining over time. Their measure of importance is the number of citations received. Given the government's funding priorities, it is not surprising that university patenting is particularly intensive in the areas of pharmaceuticals and medical technologies.

To be sure, scientific significance does not equate to commercial significance. Especially in the health care area, there has been substantial controversy surrounding the issue of whether technological innovation has improved efficiency, on balance, or whether the costs have exceeded the relevant benefits. The critical notion here is that hospitals compete against each other, in part, by investing in new technology. Since the expected private returns to investment in new diagnostic and treatment procedures include the net revenues competed away from other hospitals, the average social rate of return to introducing new technology in individual hospitals might well be lower than the average expected private rate of return. This controversial issue is difficult to resolve empirically. Indeed, case studies highlight the difficulties associated with quantifying the net benefits of new technology and, by extension, publicly funded technological activities in this area.

Perhaps the most careful attempt to quantify the net benefits of new health care technology is Baily and Garber's (1997) comparison of the relative productivity of the U.S., British and German health care systems in treating a set of illnesses, including diabetes, breast cancer, lung cancer and gallstones. In their comparison, the authors try to incorporate morbidity and mortality among patients into their productivity estimates. For our purposes here, their main finding is that technology adoption was an important factor affecting productivity. Specifically, faster adoption of new techniques such as CT scans generally improved productivity.

Critics of the Baily and Garber study highlight the crucial importance of their assumptions about morbidity and the controversial nature of these assumptions. In effect, output measurement problems cast some doubt on the reliability of their conclusions.[28] In a similar vein, biases in the measurement of quality-adjusted output in the pharmaceuticals industry render estimates of the net benefits of new drugs highly uncertain.[29]

The health care sector is of major importance to technology policy. For one thing, it is a relatively large sector in developed economies, and productivity growth in that sector is extremely important to the successful containment of spending growth without the sacrifice of accessibility and service quality. For another, it is the focus of a substantial amount of innovation activity in developed countries, particularly government-funded innovation activity. The serious lack of knowledge about the net social benefits of this activity therefore constitutes a substantial and worrisome gap in our understanding of the technological change process and the factors conditioning this process. This may be a particularly relevant criticism for Canada. Although Canada spends absolutely and relatively less than the United States on promoting health care technology, the presumption has been that Canada benefits from technology spillovers in this sector, as it does in the manufacturing sector. However, the previously cited studies of technology spillovers in Canadian industries shed little light on whether the spillover phenomenon extends to public sector activities such as health care. For example, it can be conjectured that Canadian health care suppliers, under the direction of government policy makers, may be relatively slow to adopt new technology developed outside the country.

FACTORS CONDITIONING THE INNOVATION-PRODUCTIVITY GROWTH LINKAGE

THIS SECTION OF THE REPORT REVIEWS AND SYNTHESIZES evidence about the factors that increase or diminish the contribution of technological change to productivity growth. In effect, it focuses on factors that promote closer and stronger linkages between technological change and productivity change. These factors can operate on at least two levels: 1) they can encourage a faster rate of technological change by accelerating and/or deepening the introduction and diffusion of new best practices; and 2) They can promote the more effective commercialization and use of new best practices.

Factors that have been identified as relevant in this regard include: 1) the education and skill level of the workforce; 2) the extent of competition in domestic industries; 3) the openness of the domestic economy to foreign trade and foreign direct investment; 4) the strength and nature of intellectual property protection; 5) the social infrastructure; and 6) government policies of various types.[30]

The linkages between government and private sector research organizations, as well as those among innovating organizations, have been the focus of what has been described in the literature as 'systems of innovation'. A set of potentially relevant linkages is provided in Table 2. In effect, the concept of a national or international system of innovation codifies the main specific sources of innovation spillovers among and between public and private sector organizations. While some evidence exists about most of the linkages identified in Table 2, the bulk of reliable statistical evidence concerns international linkages.

TABLE 2

FACTORS UNDERLYING A NATIONAL SYSTEM OF INNOVATION

Linkages with Foreign Research Institutions
National Tradition of Scientific Education
National Funding of Basic Research
Commercial Orientation of Research Institutions
Labour Mobility
Venture Capital Market
Government Role in Technology Diffusion
Collaboration with Research Institutions
Inter-Firm R&D Cooperation
Utilization of Foreign Technology

Source: Bartholomew 1997, p. 247.

INTERNATIONAL INTEGRATION

THE AVAILABLE EVIDENCE TENDS TO PROVIDE overwhelming support for the arguments that international trade and foreign direct investment are important channels for the global distribution of new technologies, and that smaller countries such as Canada are disproportionate beneficiaries of international technology flows. There is less agreement on the relative importance of specific alternative modes of international business with regard to linking technological changes to domestic productivity growth.

Potential channels for the international transmission of technical knowledge include: 1) imports of capital goods and intermediate inputs; 2) foreign direct investment; 3) joint ventures and strategic alliances; 4) technology licenses; and 5) migration of skilled labour. Some studies have attempted to evaluate the robustness of these various channels of international technology transfer, although most do not address the issue in any comprehensive manner.

Gollop and Roberts (1981) provide a relatively early contribution to this literature in their study of a sample of approximately 20 U.S. industries. They conclude that foreign-supplied intermediate inputs have important direct and indirect effects on the sectoral productivity growth of their sample of U.S. manufacturing industries. Gera, Gu and Lee (1998b) confirm this broad finding with respect to imported information technology (IT) products. In particular, they conclude that international R&D spillovers from the IT sector played a dominant role in Canada over the period 1971-93. They estimate the rate of return on R&D embodied in IT imports at about 37 percent per year over the period, while it is only around 9 percent per year on R&D embodied in non-IT imports. They also find that international R&D spillovers are insignificant for the United States, although when they distinguish between international R&D embodied in IT and non-IT imports, they find a strong and significant effect of international R&D spillovers embodied in IT imports on productivity growth.

Conversely, Mohnen (1992) focuses on the role of foreign R&D spillovers in Canadian manufacturing. His results do not suggest an effect of foreign R&D as strong as might have been anticipated. Indeed, over the period 1965-83, Mohnen estimates that foreign R&D contributed a modest 2.5 percent to total factor productivity growth in Canadian manufacturing industries. However, this contribution was relatively more significant than the contribution of domestic R&D.

Globerman, Kokko and Sjoholm (forthcoming) provide some additional insight into the nature of international channels of technology spillovers in their study of patent citations by Swedish firms. The authors examine patent citations of Swedish multinational companies (MNCs), as well as small and medium-sized enterprises (SMEs) in Sweden in order to assess whether the sources of the patents cited differ across the two samples. Their results show that Swedish firms use more references to countries with large patent stocks, as well as to countries located close to Sweden. Trade contacts and outward Foreign Direct Investment (FDI) also seem to facilitate technology diffusion. However, there seems to be some differences between MNCs and SMEs regarding the importance of the various technology transfer channels. Most notably, trade contacts appear to be more important for SMEs than for MNCs. A plausible explanation is that the latter enjoy access to information through their network of foreign affiliates, while SMEs must rely more on arms-length sources of technological information including foreign trading partners.[31]

Industry-specific studies further support the notion that the importance of specific international channels of technology transfers is context-specific. For example, international cooperative alliances are a particularly important means for firms to enhance their innovative capability in biotechnology (Bartholomew 1997). Whether this will remain true as major multinational companies emerge as important suppliers of biotechnology products is a matter for speculation.

The preceding results unveil a promising line of inquiry for Canadian research. Specifically, while the available research summarized above strongly suggests the existence of international spillovers to Canada, we are aware of no research that attempts to identify whether firms of different sizes and degrees of international exposure emphasize different international technology transfer channels. In particular, while there is an abundant literature on the nature of the technology transfer mechanism within multinational companies in Canada, the ways in which small and medium-sized enterprises assimilate and use new foreign technology have not been studied extensively.

MANAGEMENT

THE INTUITIVE NOTION is that the quality of management affects the creation and utilization of technology. In principle, effective managers should exploit available technology to promote productivity growth within their organizations. While there is some broad support for this intuitive notion in specific industry case studies (Baily and Chakrabarti 1988), there is no consensus on the characteristics that make for good technology management. Thus, Globerman (1975) found no systematic evidence that the educational background of managers was a significant factor affecting the adoption of new technology in the Canadian tool and die industry. However, more educated managers seemed more inclined to adopt new computer technology in several service sector industries (Globerman 1984).

In other cases, the influence of management might be indirect. For example, the organizational structure can influence the willingness and capability of firms to adopt and exploit new technologies. Management, in turn, presumably influences the organizational structure. An interesting study in this regard is that of

Adams and Jaffe (1996) who find that the productivity-enhancing effects of parent-firm R&D diminish with the geographical distance separating production facilities from the research laboratory, as well as with the technological 'distance' between the product field focus of the company's R&D facilities and the company's plants. Another suggestive plant-level study concludes that plants with integrated fabrication and assembly operations appear to use technology more effectively than plants engaged only in fabrication or assembly (Beede and Young 1998).

EDUCATION

IT ALSO TENDS TO BE CONVENTIONAL WISDOM that universities and technical colleges can promote the productivity-enhancing effects of new technology by, among other things, encouraging the dissemination of laboratory results to industrial practice. In principle, government research institutions can play the same role, although the absence of a teaching function these organizations deprives one mode of faster commercialization of new technology, i.e. the migration of students into industry as researchers and administrators.

Bartholomew (1997) argues that the academic environment is an important conditioning factor of national performance in the biotechnology industry. In particular, closer ties between the academic research system and industry, which can take the form of more industrial consulting by academics and more funding of academic research by industry, promote the accumulation and diffusion of technical knowledge. However, the importance of such ties may vary across countries. For example, small nations such as Canada may be able to capitalize on the research activities of foreign universities. However, in some industrial activities, the characteristics of Canadian industries may be sufficiently unique that basic and applied research conducted in foreign research institutions would be largely inapplicable in Canada.[32]

Engelbrecht (1997), among others, shows that general human capital is a vehicle of international knowledge transfer associated with productivity catch-up amongst OECD countries. That is, general human capital better equips organizations to exploit potential technological spillovers from abroad.[33] At the same time, scientific expertise in production facilities can promote faster and more effective diffusion of technology from a company's research facilities to its production facilities.

INTELLECTUAL PROPERTY PROTECTION

THERE IS A FAIRLY SUBSTANTIAL LITERATURE assessing the importance of intellectual property protection for the generation and utilization of new technology. The findings of this literature can be summarized as indicating that formal intellectual property protection is of importance only in a few industries, most notably pharmaceuticals and industrial chemicals.[34] For a small country like Canada, stronger intellectual property protection does not seem to be a promising policy to promote more robust linkages between technological change and productivity growth in most domestic industries.

VENTURE CAPITAL

YET ANOTHER ELEMENT OF CONVENTIONAL WISDOM is that venture capital financing must be available to help entrepreneurial firms commercialize new technology and ultimately enable that technology to be used to increase productivity. The available evidence offers no reason to gainsay this piece of conventional wisdom. What is much less clear in the literature is whether venture capital markets are geographically segmented and, if so, what accounts for any such segmentation. Moreover, one should not necessarily presume that concentration of both venture capital sources and high-technology activities implies that government policies encouraging the former will lead to the latter. That is, venture capital sources may follow the emergence of technological centres of excellence rather than substantially contributing to the creation of such centres.

TEMPORAL PATTERNS IN THE LINKAGES

THIS SECTION WILL ADDRESS THE SPECULATION that the relationship between technological change and productivity change has undergone profound alterations over the post-war period by considering the available evidence on the issue. One hypothesis is that the productivity payoff to science and technology declined in the 1970s and 1980s because the major scientific breakthroughs of earlier periods had been largely exploited commercially by the early to mid-1970s. A second hypothesis is that the emergence of new computer and communications technologies and related developments, such as the Internet and the World Wide Web have dramatically increased the productivity returns to investments in technological activities. A third hypothesis is that developments in international trade and investment, as well as increases in the education and skill levels of the workforce, have led to increased intra-national and international spillovers of technology, thereby increasing social rates of return to R&D and innovation but reducing comparable private rates of return.

Griliches (1988) argues against the existence of a secular decline in R&D productivity based upon the observation that manufacturing and agricultural productivity in the United States has exhibited no secular declining trend. He argues that the linkage between R&D and productivity growth is probably more stable and more readily identified in those sectors than in other sectors of the economy. Hence, if R&D productivity were declining, it should be most readily apparent in a declining productivity performance of the manufacturing and agriculture sectors.

Mohnen (1992) provides a comprehensive assessment of the literature relating productivity growth to R&D performance. The studies reviewed are primarily econometric in nature. He interprets the evidence as rejecting the notion that the productivity of own R&D has declined over time, but he considers the evidence more equivocal with respect to whether there has been a decline in the productivity of 'imported' R&D.

As Fortin and Helpman (1995) note, the decline in labour productivity during the post-1973 period does not seem associated with a decline in the capital-to-labour ratio, at least in Canada. This suggests that technological change may be the culprit. The decline in R&D intensity in many developed countries in the 1970s is potentially consistent with a future decline in productivity, although the decrease in R&D intensity does not seem sufficiently substantial to be a major part of the post-1973 productivity growth slowdown story. The more general view is that exogenous events such as the energy crisis, increased government regulation and a stronger emphasis on non-commercial objectives such as environmental remediation are more important explanatory factors.

COMPUTERIZATION AND PRODUCTIVITY GROWTH

> Information technology-broadly defined to include computers, software and communications is the most important technology today.
> (Bresnahan and Greenstein 1996, p. 2)

A NUMBER OF STUDIES FOCUS EXPLICITLY on the impact of computerization on productivity change, as well as on the factors conditioning that impact. Siegel (1997) summarizes and evaluates a number of relevant studies. His main point is that earlier studies are potentially unreliable because of biases in the measurement of computer prices and utilization, and because of a failure to explicitly acknowledge that improved labour quality usually accompanies increased computerization.[35] Previous studies also generally ignore the potential for productivity change to influence computerization as well as the reverse. These shortcomings make it likely that earlier studies have produced biased and inconsistent estimates of the linkage between productivity change and computerization.

Siegel attempts to rectify for these shortcomings by estimating a model linking total factor productivity differences across a set of four-digit (SIC) U.S. industries to differences in computer usage, as well as to other independent variables. His results imply that the marginal productivity of investment is higher for computers than for other types of capital. Moreover, he finds a positive and statistically significant relationship between productivity growth and investment in computers, with an excess estimated rate of return on computers of about 6 percent.

Conversely, Stiroh (1998) argues that sectoral differences are crucial in understanding the impact of computers. He examines data on 35 manufacturing and service sectors for the period 1947-91. He finds that the computer-producing sector enjoyed rapid TFP growth over the sample period. For other sectors of the economy, the decline in the price of real computing power encouraged a substitution away from relatively expensive labour and non-computer capital towards relatively cheap computers. However, there is no evidence that this accumulated investment in computing capacity increased TFP in using industries, on average. In a similar vein, Lehr and Lichtenberg (1996) examine trends in computer usage and the effect on productivity growth for a sample of U.S. federal government agencies over the period 1987-92. They find that computer usage contributed to productivity growth, although the impact was not dramatic.

Other studies focus more broadly on information technology (IT) and its linkages to productivity growth. One notable study in this regard for Canada is Gera, Gu and Lee (1998a). The authors study the extent to which investments in IT contribute to labour productivity growth in Canada and the United States, and whether domestic and international R&D spillovers from the IT sector are important for labour productivity growth. Their main conclusions are: 1) IT investments are an important source of labour productivity growth across Canadian industries; 2) R&D spillovers in Canada are primarily international in scope; and 3) IT investments and international R&D spillovers embodied in IT imports also have positive and significant impacts on labour productivity growth across U.S. industries, but the results are less robust than for Canada.

The OECD also considered the linkage between investment in information technology and productivity growth in an international context. Its examination underscores the difficulties in reliably identifying the precise linkage, especially in the presence of measurement errors in the relevant variables and an uncertain lag structure among the variables. Hence, while it finds a positive impact of IT capital on productivity in the service sectors of OECD countries, its statistical significance was not confirmed.

Part of the explanation of the somewhat ambivalent findings with respect to the strength of the measured linkages between computerization, investments in IT capital more generally, and productivity growth may reflect a heterogeneous experience across organizations. For example, Antonelli and Marchionatti (1998), among others, argue that only large, vertically integrated firms can bear the delays between the adoption of new information technologies and their positive effects on productivity growth.

AGREEMENTS, DISAGREEMENTS AND UNCERTAINTIES

> As progress was made, it became clearer how much we still don't know and how thin are our data.
> (Griliches 1998, p. 270)

THIS SECTION ATTEMPTS TO SUMMARIZE the major areas of agreement, disagreement and uncertainty surrounding the linkages between R&D and innovation, technological change and productivity growth.

At a relatively broad level, there is a fair degree of consensus on several issues. One is that technological change is, indeed, a major contributor to productivity growth. As a related point, there is also agreement on the fact that this contribution is not uniform across firms, industries and countries, and that the contribution of technological change to productivity growth probably has not changed substantially over the post-war period.

A second point of broad consensus is that social rates of return to R&D (and innovation, more generally) exceed private rates of return by a substantial margin. International technology spillovers are especially important for smaller countries such as Canada. International spillovers take place through a number of different channels including foreign direct investment, trade and strategic alliances. The robustness of these channels varies with the nature of the economic activity; however, it is difficult to generalize about these differences with any precision.

A third point of broad agreement is that attributes of the domestic environment influence the linkages between technological change and productivity growth. For example, the adoption of new technology, as well as the benefits derived from new technology adoption, will be functions of domestic economy attributes such as the exposure of domestic industries to competition, the general educational level of the work force, and the availability of venture capital, among other things. There is much less agreement on the relative importance of these various factors, or on whether and how the importance of individual factors varies across industries or economic activities.

A fourth broad point of agreement is that government-funded R&D has significant private sector spillover benefits, although most of the evidence pertains to U.S. government activity, and the results may be idiosyncratic to an individual government experience. It is also agreed that basic research provides important spillover benefits and is a strong complement to private sector R&D activities. The factors that condition the spillover benefits from public sector R&D funding and performance are less clear. Obviously, the closer the integration between government and private sector research laboratories, the more complementary private and public sector R&D are likely to be. However, it is unclear how to best structure this integration. As well, the literature tends to ignore the 'public choice' aspects of any such integration, i.e. will it lead to increased funding of projects with relatively high private rates of return and relatively low social rates of return?

A fifth point of agreement is that formal intellectual property protection is an important determinant of technological behaviour only in some industries.

Finally, virtually all economists agree that the measurement of both productivity change and technological change is highly problematic and that it is likely that official estimates are seriously biased. They also agree that the estimation of the relevant linkage between technological change and productivity change is extremely difficult. In particular, it is subject to daunting statistical difficulties, while case study approaches to their issue suffer the potential weakness of being case-specific.

Most of these points of agreement are relevant in the Canadian context. However, there are attributes of the Canadian experience that are arguably less well established than for other countries, especially the United States. In particular, there is a significant body of evidence suggesting that rates of return to R&D are lower in Canada than in other developed countries and, indeed, may be statistically insignificant across broad samples of firms and industries. The reasons for such differences remain unclear, notwithstanding claims that they reflect Canada's industrial structure including relatively high levels of foreign ownership and a relatively large primary manufacturing sector.

From both a Canadian and an international perspective, it seems fair to conclude that we know relatively little about the linkage between technological change and productivity change in major public-sector activities such as health care and education. Indeed, while it is suggested that the advance in IT technology is, perhaps, the major future source of productivity growth in service industries, most available studies of the linkages between technological change and productivity growth have focused on manufacturing industries and even agriculture. We know comparatively so little about the welfare impacts of technological change in the health care sector, for example, that whether technological change in this sector is welfare improving or welfare decreasing, from a social perspective, is a matter of strong debate.

Correspondingly, most of our understanding of international technology spillovers is associated with the experience of manufacturing industries. Given the size and policy importance of service sectors such as health care and education, the relative paucity of information about international technology spillovers for these sectors is a major shortcoming. In particular, given the very limited trade and cross-border investment taking place in these sectors, there are grounds for real concern that Canadian suppliers are not benefiting from the strong spillover benefits realized by Canadian manufacturers.

Future Research Agenda

IDENTIFICATION AND PRIORITIZATION OF A RESEARCH AGENDA will ultimately reflect the biases of the researcher. For example, Griliches (1998) sets out a research agenda that emphasizes dealing with econometric and variable measurement problems that have plagued earlier statistical studies of the linkage between R&D and productivity growth. Others underscore the merits of a broader focus on the innovation structure of a country including the role that educational and government research institutions play in the innovation and diffusion process.

While it is certainly important to refine our understanding of measurement and econometric problems plaguing statistical identification of the linkage between technological change and productivity change, my view is that Canadian policymakers would benefit more from examinations of more basic issues:

1. Perhaps first and foremost, we know very little about the role of technological change in the delivery of health care services in Canada beyond the obvious fact that new technology has been adopted by Canadian health care providers and that health care practices have changed accordingly. For example, we are far from a consensus about whether technological change is proceeding too rapidly or too slowly from a productivity perspective. We also know relatively little about the channels through which international technology spillovers occur in this sector, or about the robustness of the channels, or, indeed, whether the institutional arrangements of the Canadian health care sector strongly condition the international technology spillover process. While similar statements can be made about other public sector activities such as education, the relative size and policy prominence of the health care sector would seem to dictate that priority be give to addressing the relevant gaps in our knowledge about this sector.

It would seem that alternative approaches to filling this knowledge gap are potentially viable, although, as noted above, measuring productivity in this sector is extremely difficult. Nevertheless, the emergence of studies identifying the adoption of new procedures and techniques in different countries, as well as the consequences of those innovations, offers the basis for a comparison between Canada and other countries. For example, would econometric or more qualitative studies show that productivity-enhancing medical innovations are being adopted at a slower rate in Canada than elsewhere? If so, what factors are contributing to this phenomenon? Is international technology transfer to Canada proceeding more slowly in the health care sector than in manufacturing? And so forth.

Obviously, similar questions can be raised about the educational sector. Budgets permitting, a similar research focus on the educational sector could be justified for reasons similar to those relevant to the health care sector. The fact that there is a fairly substantial private educational system offers the basis for an additional perspective on the main issue of interest. Specifically, it enables a direct examination of differences that ownership incentives make in adopting and exploiting new technology to promote productivity growth.

2. As noted above, available evidence suggests that rates of return to privately funded R&D in Canada are generally lower than in the United States and perhaps in other developed countries. The reasons for any such gap are unclear, although numerous hypotheses have been posited. The majority of Canadian studies have focused on the determinants of R&D intensity in Canada, rather than on the determinants of the marginal productivity of technology inputs. Yet the latter issue is clearly important, since promoting a higher R&D intensity may be an inferior policy measure if public resources spent on improving the yield of innovation activities in Canada have larger net social benefits.

There are various approaches to studying this issue. However, it would seem that the most promising approach would involve a number of careful case studies in which relatively homogeneous samples of Canadian firms would be compared to similar samples of foreign firms. The samples could be constructed to represent various manufacturing and service industries. It is unlikely that published data would be sufficiently detailed to permit an adequate examination of the relevant issues. Indeed, it seems more likely that an original data set would need to be constructed.

It is not possible to consider here all the difficulties associated with this task. However, it would seem possible to gather sufficient original data, perhaps through surveys, to produce estimates of productivity growth and of rates of adoption of new production techniques. With data on other firm- and plant-level attributes of the sample organizations, it would seem possible to undertake a statistical examination of the factors conditioning the linkage between productivity growth and new technology adoption. Thus, one might estimate productivity growth equations in which the technology-adoption variable is interacted with variables such as the educational background of managers and workers, the size and scope of the organization and so forth, to see which factors, if any, significantly enhance or diminish the strength of the linkage between productivity growth and innovation adoption. The values of the significant variables could be compared between the Canadian and non-Canadian samples to shed some light on the specific factors that might account for a lower (or higher) productivity payoff to new technology adoption in Canadian organizations.

3. A third broad focus of the Canadian research agenda might be to contrast and compare the role of Canadian universities to U.S. universities in promoting and enhancing the linkages between technological change and productivity change in Canada. Most of the focus of policy-oriented research in Canada has been on the nature of university-industry collaboration in domestic innovation activities. Virtually no attention (of which we are aware) has been paid to the issue of how Canadian universities bring foreign-developed technology into the Canadian economy, and whether and how Canadian universities are promoting international technology spillovers in Canada. Given the documented importance of international technology spillovers to Canadian productivity growth, this would seem to be of importance to Canadian policy makers.

Various possible approaches might be taken to address this issue. For example, patents issued to Canadian university-based researchers might be examined to identify citations to other patents. Whose patents are being cited? Compared to a comparable sample of, say, Swedish university-based researchers, are Canadian researchers more likely to cite foreign sources in their patent applications, all other things constant? Are Canadian university-based researchers as likely to file patents jointly with foreign researchers as, say, Swedish university-based researchers, or their counterparts in U.S. universities, all other things constant. If patent data did not permit an adequate examination of this issue, it might be feasible to construct an original data set through interviews with Canadian university technology liaison offices.

ENDNOTES

1 See, for example, Chipello and Ricklefs (1999). There is a good deal of controversy surrounding recent estimates by Statistics Canada of Canadian productivity performance. See, for example, McCarthy (1999).

2 In his February 1999 budget, Finance Minister Paul Martin highlighted the government's view that more R&D and innovation is critical to improving productivity growth in Canada and promised financial incentives to encourage increased technological activity in Canada.

3 *Ibid.*

4 For a temperate perspective on this issue, see Bresnahan and Greenstein (1996).

5 An early seminal review of the technological performance of Canada, as well as its causes and consequences, is provided in the Report of the Senate Special Committee on Science Policy (1970).

6 A non-technical discussion of the various productivity indices is provided in Baily and Chakrabarti (1988). A more technical discussion is found in Wagner and van Ark (1996). It has been shown that for U.S. calculations, productivity measures tend to be in agreement as to which industries have high versus low productivity growth rates; however, this is not necessarily the case for other countries. See Mann (1997).

7 Estimation results can be sensitive to the precise output measure selected, although it is beyond the scope of this report to consider the differences. The interested reader might consult Basu and Fernald (1995).

8 The consequences of failing to adjust accurately for input and output quality changes are discussed in a later section.

9 Englander (1988) reports some evidence suggesting that measurement problems may make it difficult to derive any useful inferences on short-term and medium-term evaluation of total factor productivity.

10 The endogenous growth literature describes the potential for essentially increasing returns to investment in technological change. In effect, the marginal product of technology as an input to production can be expected to increase as expenditures on technology increase. This view cuts against the traditional notion of diminishing returns to any factor input. For an overview of the endogenous growth literature, see Howitt (1996).

11 See, for example, Bernard and Jones (1996).

12 It should be explicitly acknowledged that R&D expenditures are inputs to the technological change process. The usual presumption is that productivity change is directly related to R&D expenditures; however, the nature and magnitude of the linkage between the two quantities is ultimately an empirical question.

13 We shall review the evidence on this and related points in a later section. For a perspective on these issues, see Henderson, Jaffe and Trajtenberg (1998).

14 Lev and Sougiannis (1998) demonstrate empirically that the identification of the (private) economic benefits of R&D expenditures is sensitive to the assumed pattern for amortizing past R&D expenditures.

15 These issues are discussed in Griliches (1998).

16 Issues associated with the use of patents as an indicator of technological change are comprehensively discussed in Griliches (1990).

17 For an example of this approach, see the industry case studies in Baily and Chakrabarti (1988). In the Canadian context, see Baldwin, Diverty and Sabourin (1996).

18 This debate and the surrounding literature is reviewed in Globerman (1985a).

19 Major reviews of the literature can be found in Griliches (1998) and Mairesse and Sassenou (1991).

20 For a review of this literature, see Baily and Chakrabarti (1988).

21 Estimates of the rate of return to investment in R&D can be indirectly derived by multiplying the relevant output elasticities by the appropriate ratios of R&D to capital stocks. See Coe and Helpman (1995).

22 The inter-industry spillover variable is defined as the sum of the R&D capital stocks for all other industries lagged one period. The intra-industry variable for any corporation in the sample industry is defined as the sum of the R&D capital stocks of all rival firms in the same industry, lagged one period.

23 Several industry-specific studies also fail to identify a statistically significant relationship between R&D and productivity growth. For example, Mohnen, Jacques and Gallant (1996) find that R&D in Canada's pulp and paper and wood industries had a minimal impact on TFP growth over the period 1963 to 1988. However, the estimated rate of return, while lower than for some countries such as the United States and Finland, was higher than for others such as Sweden.

24 The large presence of Northern Telecom's manufacturing facilities in the United States suggests the plausibility of this inference in the case of this large R&D performer.

25 Estimated rates of return are in the 30-40 percent range, which is consistent with the results cited by Mohnen (1992).

26 Exceptions to this statement have been identified. For example, Bernstein and Mohnen (1998) find that there are international spillovers from the United States to Japan but not in the reverse direction. As well, the own-R&D variable has been found insignificantly related to productivity growth in other countries beside Canada, for example Korea. See Kim and Nadiri (1996).

27 See, for example, Basant and Fikkert (1996). This is also apparently true for spillovers that occur at the plant level. That is, spillovers affecting plant-level productivity are a function of firm-level R&D intensity. See Adams and Jaffe (1996).

28 See Cutler (1997).

29 For a discussion of this point, see Berndt, Cockburn and Griliches (1996).

30 The relevant body of literature is broadly concerned with national and international systems of innovation. For a seminal contribution to this literature, see Nelson (1993).

31 Henderson, Jaffe and Trajtenberg (1993) examine geographical patterns of patent citations. They find that citations to domestic patents are more likely to be domestic and more likely to come from the same State and Standard Metropolitan Statistical Area compared with a control frequency reflecting the pre-existing concentration of related research activity.

32 For a discussion of this issue in the context of the Canadian forest products industry, see Globerman, Nakamura, Ruckman and Vertinsky (1998).

33 More generally, an educated work force presumably enables new technology to be introduced sooner and adopted more quickly in national economies. More literate and numerate workers are easier to train in the use of new technology and, arguably, less likely to resist the introduction of new technology. For a review of the theory and evidence on this issue, see Globerman (1985b).

34 The convergence between pharmaceutical and biotechnology R&D suggests that intellectual property protection is also likely to be of importance to biotechnology companies.

35 A similar point is made in Griliches (1994).

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10

The Importance of Innovation for Productivity

INTRODUCTION

RAPID TECHNOLOGICAL CHANGES, the information revolution and increasing globalization of business activities have intensified competition among countries for export markets, capital, R&D, and skilled people. The competitive imperative is especially critical for Canada because it depends heavily on international trade and foreign capital and competes head on with the United States, the world's largest and most dynamic economy, for capital, R&D, skilled people and high value-added activities.

In the 1990s, the growth rate of real per capita income in Canada was significantly lower than in other OECD countries, particularly the United States. The most often cited reason for the phenomenal productivity performance in the U.S. economy is its dynamism and superior innovation record. If innovation is the key to improving growth in productivity and living standards, it is important to examine the key drivers of innovation and to understand the nature and sources of Canada's innovation gap.

Canada's economic performance in the 1990's lagged far behind that of the United States — real incomes in Canada are currently about 30 percent below those in the United States. Although Canada has achieved a 10 percent annual growth in nominal merchandise exports over the decade (from $152.1 billion in 1990 to $360.0 billion in 1999), this has been due largely to a buoyant U.S. economy and the real depreciation of the Canadian dollar. However, we cannot rely on a weak dollar and the strength of the U.S. economy to improve the living standards and quality of life of Canadians. On the contrary, the depreciating currency may actually erode our living standards. The reality is that 90 percent of the income gap between Canada and the United States is due to the productivity shortfall. Therefore, only superior productivity performance will improve Canada's international cost competitiveness on a sustained basis, raise the

* *Now at Finance Canada*

standard of living and close the real income gap between Canada and the United States.

The research to date strongly suggests that technical progress — the embodiment of innovation — is the fundamental determinant of longer-term productivity performance, hence of international competitiveness, living standards and quality of life. The main objective of this study is to analyze the linkages between innovation and productivity. We hope to shed some new light on the following four important research questions:

- What does the cross-country data show about the importance of innovation for productivity and living standards?
- How strongly is inter-industry variation in manufacturing sector productivity correlated with the key indicators of innovation activity in Canada and the United States?
- What are the major determinants of innovation?
- How does Canada compare with other G-7 countries in terms of the key drivers of innovation?

The next section provides a conceptual framework for different dimensions of innovation, examines the theoretical linkages between innovation and productivity, and discusses the foundations of various forms of innovation. The third section explores the relationship between productivity and the key indicators of innovation, both internationally and across Canadian and U.S. manufacturing industries. In the fourth section, we look at the international evidence on the major determinants of innovation. In the fifth section, we compare Canada's innovation record with that of other G-7 countries. In the last section, we summarize the main results of our research and examine the implications of our findings.

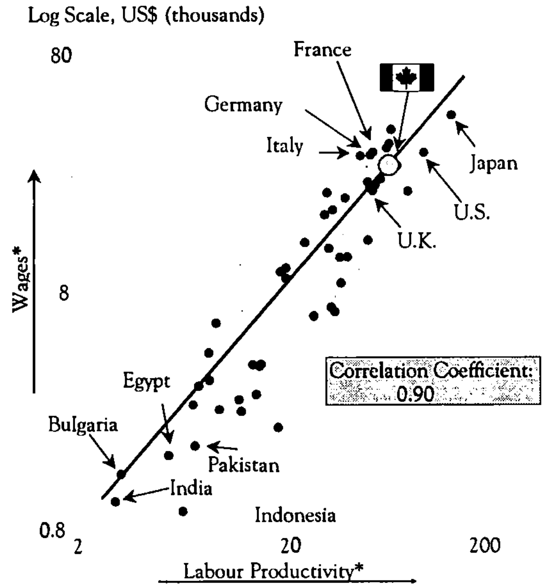
CONCEPTUAL FRAMEWORK

KEY DRIVERS OF PRODUCTIVITY

LABOUR PRODUCTIVITY LEVELS and real wages are strongly and positively correlated across developed and developing countries — i.e. low-wage countries such as India and Pakistan also have low labour productivity, while high wage countries such as the United States and Canada exhibit high labour productivity (Figure 1). The central role of productivity in determining living standards and quality of life has given rise to an extensive literature on the factors influencing its level and growth (Stiroh, 2002, and Elias, 2000, for a survey of the literature).

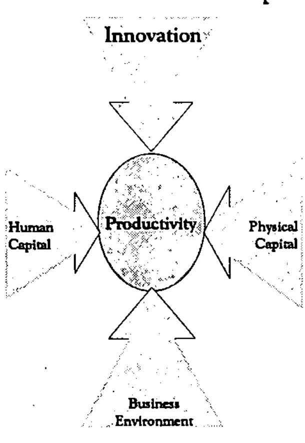
FIGURE 1

WAGES AND PRODUCTIVITY, INTERNATIONAL EVIDENCE, 1993



Note: * In manufacturing.
Source: *International Yearbook of Industrial Statistics*, 1998.

Modern growth theory identifies three key determinants of productivity growth: the accumulation of physical capital, the accumulation of human capital, and the rate of innovation and technological change. It is not appropriate, however, to consider them as separate factors, since they interact in complex ways and are complementary in nature. Advanced technologies are generally incorporated in the production process to improve productivity. But new investments in machinery and equipment, and skills development in the labour force are also required to use effectively state-of-the-art technologies. In short, the quantity and quality of these three key factors, and the way in which they are organized, managed and utilized within a firm determine productivity performance.



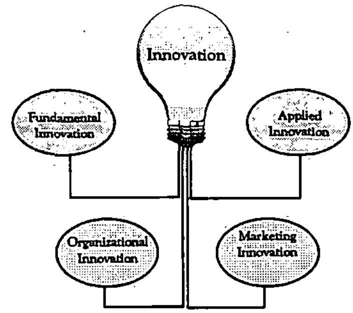
Aside from these three determinants, a country's business environment also matters. In particular, framework conditions, such as openness to trade and investment, the degree of competition within the economy, the financial system, the quality of management and the protection of intellectual property are important enabling factors for improving productivity. In particular, the degree of competition in a country or sector may be one of the most important factors, since a lack of competition reduces the pressures on firms to adopt and use advanced technologies, re-organize the workplace, rationalize production and improve productivity.

Several recent studies commissioned by Industry Canada on productivity issues provide an overview of what economists know to date about productivity, and summarize what consensus has emerged about the drivers of productivity growth and the special role played by innovation. In his literature survey, Harris (2002) identifies three key productivity drivers: investment in machinery and equipment, human capital, and openness to trade an investment — all within an overall framework where innovation creates opportunities for growth. He also identifies several other factors, including: innovation and technology diffusion, and general purpose technologies, to name just two. Globerman (1999) focuses on the literature dealing with technological change as a key driver of productivity growth. He notes a growing perception that major technological developments in computing and telecommunications, including the emergence of the Internet, will induce productivity growth. He identifies R&D expenditures and patent intensity as proxies for this type of technological change. He too emphasizes the importance of innovation for productivity. Morck and Yeung (2002) review the economic determinants of innovation and identify several key factors, including, among others: intellectual property rights, the quality of corporate decision-making, and a well-functioning financial system.

INNOVATION AND PRODUCTIVITY

THE LINK BETWEEN INNOVATION AND PRODUCTIVITY GROWTH receives particular attention in the literature. In fact, innovation is often thought of as the "engine of growth" because of its lasting long-run effects on productivity. Although the conceptual links between innovation and productivity are strong and clear, the nature of the relationship between the two is complex.

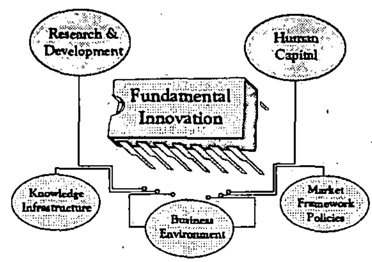
Innovation is the continuous process of discovery, learning and application of new technologies and techniques from many sources. Many techniques and processes are cumulative and interdependent, and the technological capacity of a firm may also be influenced by external factors such as the educational system, the research infrastructure and the functioning of the capital markets.



In this context, innovation includes both fundamental and applied innovation. In addition, innovation can take the form of organizational and marketing changes that expand the demand for products, support existing structures for new methods of production and increase the efficiency of other types of innovative efforts, leading to productivity improvements. Although these factors can play a very important role in increasing productivity, in this paper we focus only on technological innovations, because of a lack of data on these innovative activities and because of resource constraints.

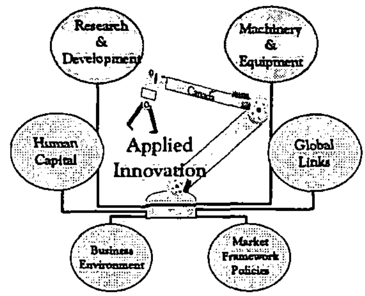
Fundamental innovation, often thought of as research proper, comprises the invention of new products and processes. It is a familiar concept, often measured by patents granted or active patents, sometimes adjusted for quality. The R&D intensity (the R&D/GDP ratio), an input measure, is also used by many as a proxy for fundamental innovation.

Investment in R&D and the accumulation of human capital, especially the share of scientists and engineers in the total labour force, are crucial prerequisites for fostering fundamental innovation. Fundamental innovation also depends on the quality of supporting institutions such as the knowledge infrastructure (universities, government labs, etc.), a healthy business environment and sound market framework policies (competition and intellectual property protection, etc.). They provide a favourable environment for innovative activity.



Fundamental innovation, however, is only a small part of the total innovative effort, especially in a small open economy like Canada. The greater part of innovation actually consists of applied innovation which occurs when new products or processes developed either in Canada or in other countries, especially the United States are adopted, or when existing technologies are used in a new context or in a new way.

Like fundamental innovation, applied innovation is also enhanced by investments in R&D and human capital. In addition, investments in machines and equipment (M&E) and strong global links are important for the adoption and diffusion of new innovative processes and techniques. Finally, supporting institutions provide positive feedback on the innovation process.



Innovation and Productivity: Empirical Findings

International Evidence

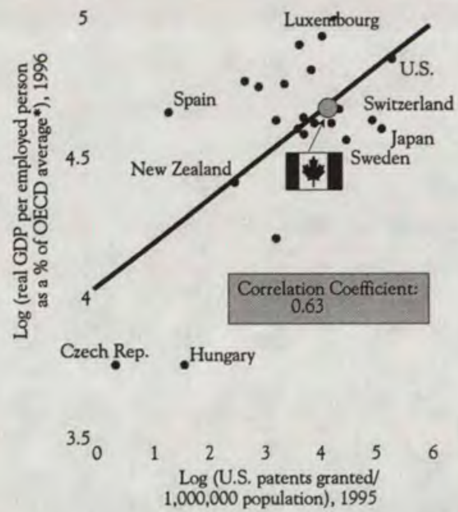
Per capita real income and productivity levels vary a great deal across OECD countries. The interesting question is whether differences in fundamental innovation activity explain the observed differences in productivity and income levels among OECD countries. We use two measures of fundamental innovation in this context: the number of patents granted in the United States per capita and the number of active patents per capita. Since the United States is the world's largest and most dynamic market, there is intense competition for obtaining a patent in that country. Therefore, the number of U.S. patents granted per capita is expected to be a good proxy for fundamental innovation. Similarly, the number of active patents better reflects fundamental innovation than the number of patent applications or of patents granted.

As expected, labour productivity levels are positively correlated with patent activity across OECD countries (Figure 2 and Table 1). Firstly, the gap between a country's labour productivity and the OECD average is positively correlated with the number of U.S. patents granted to nationals of that country. Further, the number of U.S. patents granted explains about 40 percent of cross-country variations in the productivity gap within the OECD, and a 10 percent increase in U.S. patents granted results in a 1.6 percent increase in a country's relative labour productivity. Secondly, GDP per capita is positively correlated with the number of domestic patents in force. Per capita patents in force explains about 76 percent of the cross-country variation in GDP, and a 10 percent increase in patents in force results in a 2.9 percent increase in GDP per capita.

We could not include developing countries in our sample because reliable data on labour productivity for these countries are not available. However, there is no reason to expect that the strong positive relationship observed for the OECD countries will not hold for a sample of OECD and developing countries.

FIGURE 2

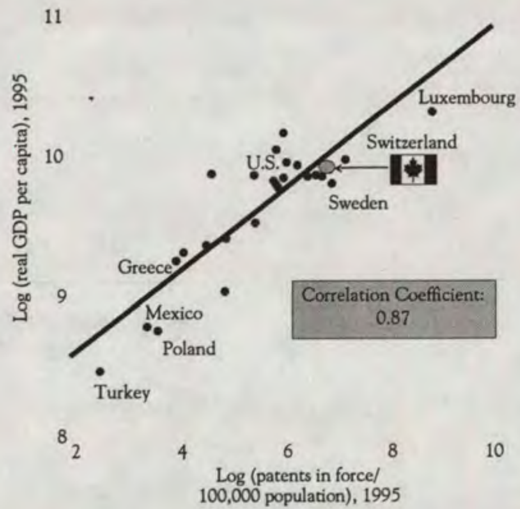
REAL GDP PER EMPLOYED PERSON* AND U.S. PATENTS GRANTED PER CAPITA, OECD COUNTRIES



Note: * The OECD average is a weighted average based on 1996 PPPs.

Source: Industry Canada compilations based on data from the OECD and the U.S. Patent and Trademark Office.

REAL GDP PER CAPITA* AND PATENTS IN FORCE PER CAPITA, OECD COUNTRIES**



Notes: * In $US based on 1990 prices and PPPs.

** Excluding Italy and the United Kingdom, for which data on patents in force are not available.

Source: Industry Canada compilations based on data from the United Nations.

TABLE 1

INNOVATION AND PRODUCTIVITY: CROSS-COUNTRY ANALYSIS, 1995

EQUATION 1 DEPENDENT VARIABLE: LN (REAL GDP PER EMPLOYED PERSON AS A PERCENTAGE OF OECD AVERAGE)		EQUATION 2 DEPENDENT VARIABLE: LN (REAL GDP PER CAPITA)	
Intercept	4.01 * 25.68	Intercept	7.94 * 41.01
Patents Granted	0.16 * 3.72	Patents in Force	0.29 * 8.75
Adjusted R^2	0.37 *	Adjusted R^2	0.75 *
Patents Granted = ln (U.S. patents granted/ 1,000,000 population)		Patents in Force = ln (patents in force/ 1,000,000 population)	

Note: * Statistically significant at the 1% level.

THE CANADIAN EVIDENCE

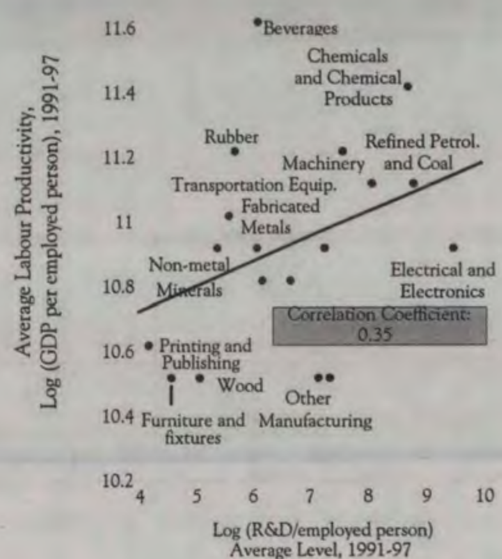
IN ADDITION TO THE INTERNATIONAL EVIDENCE, we examine the linkages between innovation and productivity across two-digit manufacturing industries in Canada and the United States. We restrict our analysis to manufacturing industries because productivity data for non-manufacturing industries suffer from serious measurement problems. Furthermore, non-manufacturing industries are much more heterogeneous than manufacturing industries. Since data on patents and on the adoption and use of advanced technologies in individual manufacturing industries are not available, we use R&D intensity, M&E intensity and human capital intensity as the key indicators of innovation activity, based on the discussion presented in previous sections. We use two measures of productivity: output per employed person and total factor productivity (TFP) growth.

As expected, all three indicators of innovation are positively correlated with the level of labour productivity across Canadian manufacturing industries. Similarly, TFP growth is significantly and positively correlated with the three measures of innovation (Figures 3 to 5). However, when the three indicators of innovation are combined in a regression analysis, the ensuing results are weak (Table 2). While human capital, M&E intensity and R&D intensity are jointly significant determinants of average TFP growth across Canadian manufacturing industries, the adjusted R^2 is low (0.24) and none of the innovation indicators is, individually, a significant regressor, although they are jointly significant at the 10 percent level. When the innovation measures are regressed on average labour productivity, the adjusted R^2 is only 0.11 and none of the regressors is significant, individually or jointly. In addition, the coefficient on R&D intensity is negative, although this is inconclusive as the t-statistic is very low for this variable.

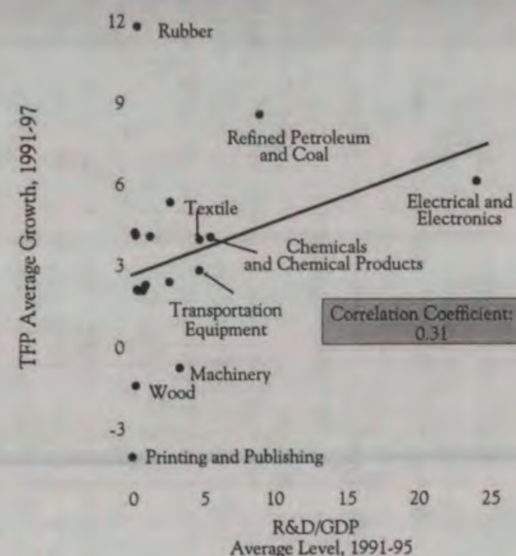
These results give qualified evidence on the relationship between innovation and productivity in Canada. While the innovation indicators do vary to a small degree in conjunction with both the level of labour productivity and TFP growth in Canada, the relationship is weak. Nor does the available evidence from the regression analysis allow us to differentiate the independent effects of each type of innovative activity on productivity. This is particularly true for R&D intensity that is highly correlated with human capital in the regression on labour productivity levels. However, the positive relationship between the innovation indicators and average TFP growth imply that a one-time level increase in innovative activity may raise the rate of productivity growth indefinitely.

FIGURE 3

R&D SPENDING PER WORKER AND LABOUR PRODUCTIVITY LEVELS IN MANUFACTURING



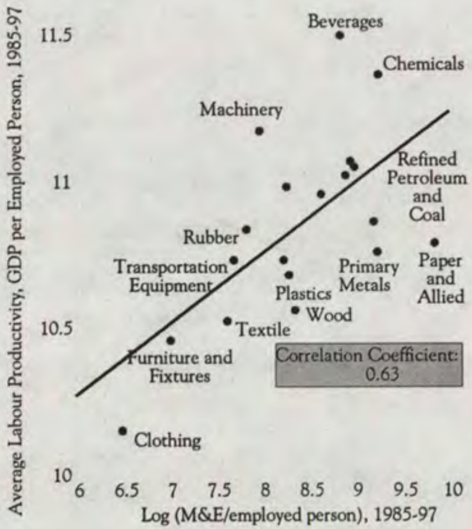
R&D INTENSITY AND TOTAL FACTOR PRODUCTIVITY GROWTH IN MANUFACTURING

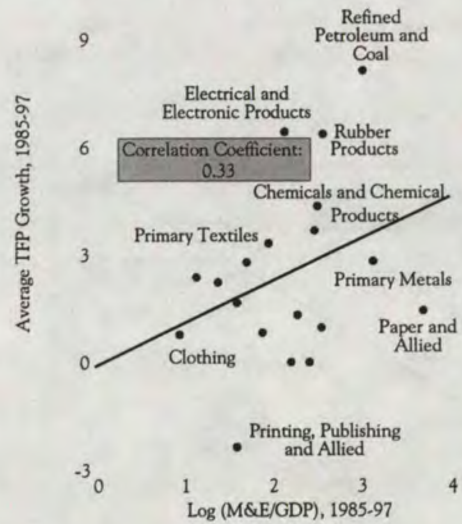


Source: Industry Canada compilations based on unpublished data from Statistics Canada.

FIGURE 4

M&E SPENDING PER WORKER AND LABOUR PRODUCTIVITY LEVELS IN MANUFACTURING	M&E INTENSITY AND TOTAL FACTOR PRODUCTIVITY GROWTH IN MANUFACTURING

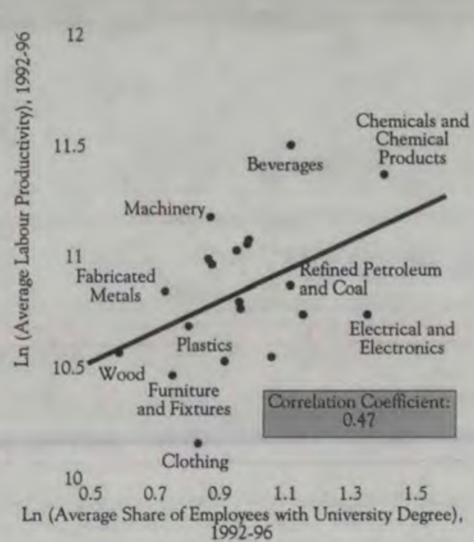




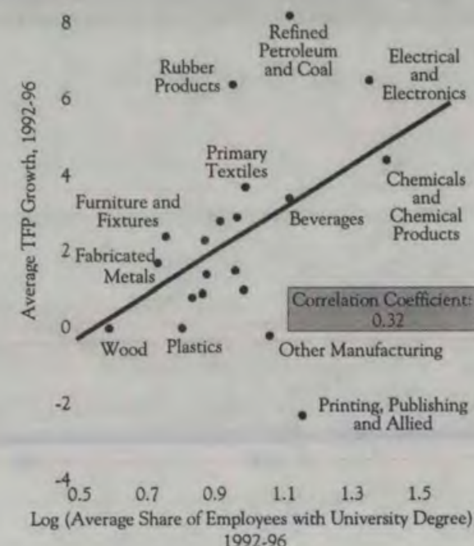
Source: Industry Canada compilations based on unpublished data from Statistics Canada.

FIGURE 5

HUMAN CAPITAL CONTENT AND LABOUR PRODUCTIVITY LEVELS IN MANUFACTURING



HUMAN CAPITAL CONTENT AND TOTAL FACTOR PRODUCTIVITY IN MANUFACTURING



Source: Industry Canada compilations based on unpublished data from Statistics Canada.

TABLE 2

PRODUCTIVITY AND INNOVATION: CROSS-INDUSTRY EVIDENCE FROM THE CANADIAN MANUFACTURING SECTOR, 1987-97

	EQUATION 1 DEPENDENT VARIABLE: AVERAGE LABOUR PRODUCTIVITY, LN (GDP PER EMPLOYED PERSON)		EQUATION 2 DEPENDENT VARIABLE: AVERAGE TFP GROWTH
Intercept	9.49 * 11.60	Intercept	-1.92 -0.53
Human Capital	0.50 1.29	Human Capital	1.70 0.48
M&E Intensity	0.11 1.05	M&E Intensity	0.82 0.89
R&D Intensity	-0.01 -0.18	R&D Intensity	0.21 1.66
Adjusted R^2	0.11	Adjusted R^2	0.25 **

Human Capital :	ln (average share of employees with university degrees)	Human Capital :	ln (average share of employees with university degrees)
M&E Intensity :	ln (M&E per employed person)	M&E Intensity :	ln (M&E/GDP)
R&D Intensity :	ln (R&D per employed person)	R&D Intensity :	ln (R&D/GDP)

Notes: * Statistically significant at the 1% level.
** Statistically significant at the 10% level.

THE U.S. EVIDENCE

AS IN CANADA, the correlation between the three innovation variables and labour productivity levels across U.S. manufacturing industries is highly positive and statistically significant, but significantly stronger than in Canadian industries (Figures 6 to 8). On the other hand, the correlation between TFP growth and the three innovation measures is significantly weaker in U.S. industries.

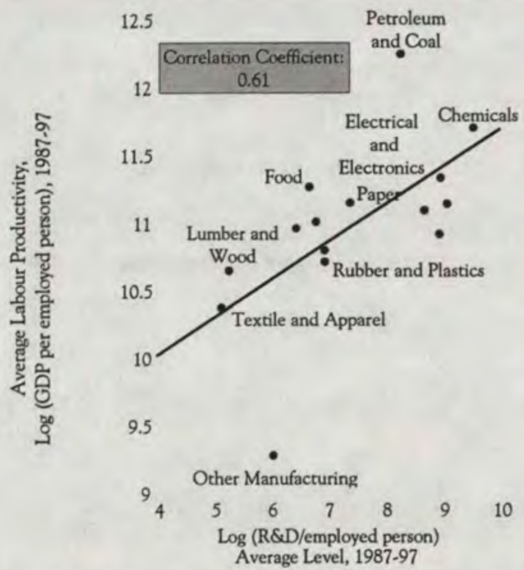
The discrepancy between the Canadian and U.S. results is even more pronounced when we turn to the regression results for U.S. manufacturing industries (Table 3). Again, average labour productivity levels and average TFP growth were regressed on the three indicators of innovative activity: human capital, M&E intensity and R&D intensity. The adjusted R^2 when innovation indicators are regressed on average labour productivity is 0.84, while the adjusted R^2 when innovation indicators are regressed on TFP growth is -0.27. The large difference between the two countries is interesting but puzzling. It may reflect the fact that the United States is the technological leader and relies more heavily on fundamental innovation to maintain productivity than Canada. If this is the case, then U.S. TFP growth could depend more on the rate of *increase* in fundamental innovation rather than on the level of innovation. At the same time, Canada relies more heavily on the adoption and diffusion of new technologies and less on fundamental innovation.

The regression results also provide an indication of which innovative activities have the strongest effects on labour productivity levels across U.S. manufacturing industries. Again, in the United States, as in Canada, the coefficient for R&D intensity is negative. However, the presence of multicollinearity between the variables, and the high correlation between R&D per employed person and average labour productivity indicate that the effect of R&D intensity on labour productivity levels is not easily separated from that of other innovative activities. That being said, it appears that M&E intensity has the strongest effect on the level of labour productivity among U.S. manufacturing industries. The regression coefficients indicate that a 10 percent increase in M&E intensity leads to a 4.3 percent increase in labour productivity, compared to a 0.3 percent increase only in labour productivity for a 10 percent increase in human capital, all else held equal. Thus, the most effective mechanism for increasing labour productivity in U.S. manufacturing industries is an increase in M&E intensity.

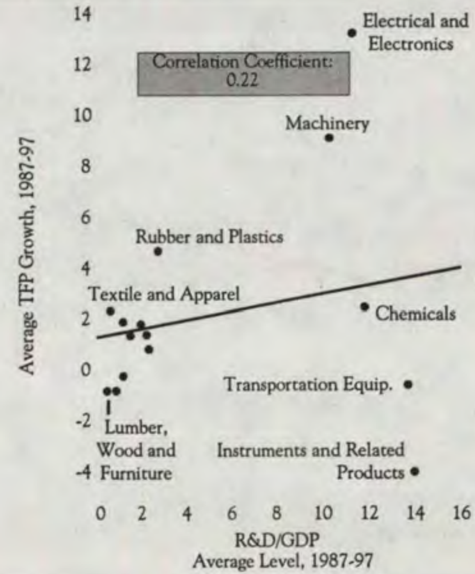
In conclusion, both the international and the Canadian and U.S. evidence strongly suggest that innovation is a key driver of productivity and that of the three indicators of innovative activities examined, M&E investment has the strongest impact on productivity independent of the interactions of investment and productivity. In addition, for Canada, the results also suggest that a one-time boost to innovative activity could positively and permanently raise the rate of growth of productivity.

FIGURE 6

R&D SPENDING PER WORKER AND LABOUR PRODUCTIVITY LEVELS IN U.S. MANUFACTURING



R&D INTENSITY AND TOTAL FACTOR PRODUCTIVITY GROWTH IN U.S. MANUFACTURING

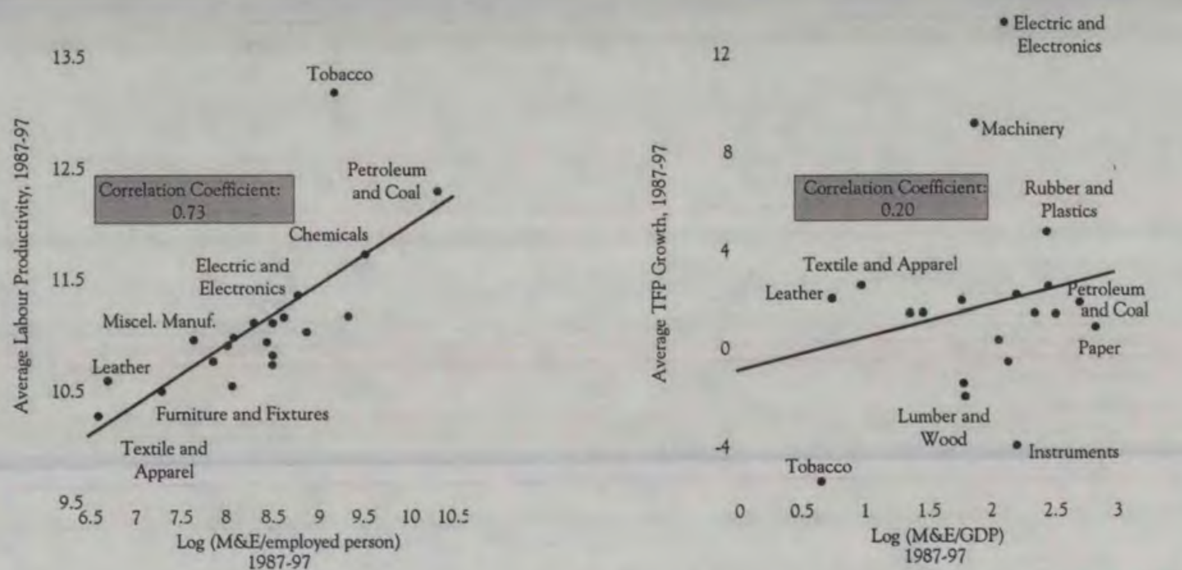


Source: Industry Canada compilations based on unpublished data from the U.S. Bureau of Economic Analysis (BEA).

FIGURE 7

M&E SPENDING PER WORKER AND LABOUR PRODUCTIVITY LEVELS IN U.S. MANUFACTURING

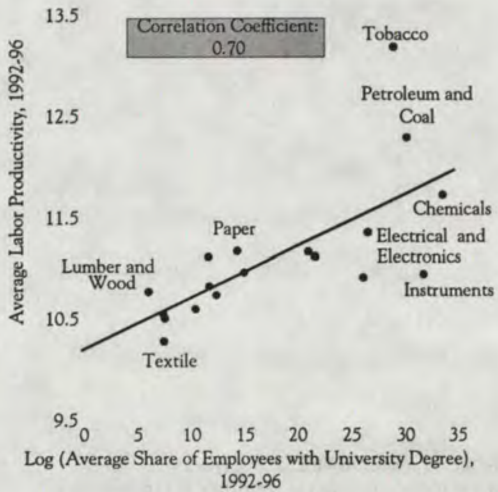
M&E INTENSITY AND TOTAL FACTOR PRODUCTIVITY GROWTH IN U.S. MANUFACTURING



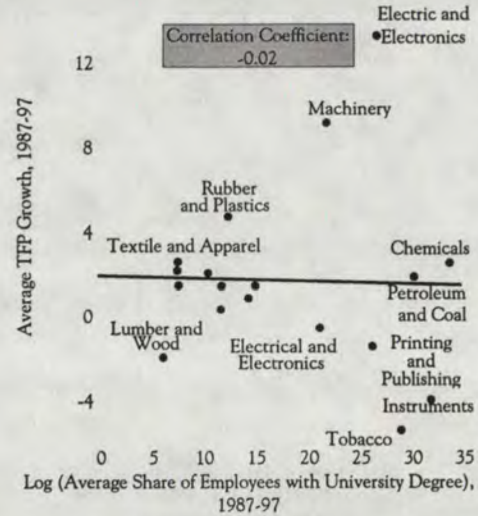
Source: Industry Canada compilations based on unpublished data from the BEA.

FIGURE 8

HUMAN CAPITAL AND LABOUR PRODUCTIVITY LEVELS IN U.S. MANUFACTURING



HUMAN CAPITAL AND TOTAL FACTOR PRODUCTIVITY GROWTH IN U.S. MANUFACTURING



Source: Industry Canada compilations based on unpublished data from the BEA.

TABLE 3

PRODUCTIVITY AND INNOVATION: CROSS-INDUSTRY EVIDENCE FROM THE U.S. MANUFACTURING SECTOR, 1987-97

EQUATION 1 DEPENDENT VARIABLE: AVERAGE LABOUR PRODUCTIVITY, LN (GDP PER EMPLOYED PERSON)		EQUATION 2 DEPENDENT VARIABLE: AVERAGE TFP GROWTH	
Intercept	7.83 *	Intercept	2.73
	11.67		0.44
Human Capital	0.03 **	Human Capital	0.06
	2.36		0.23
M&E Intensity	0.43 *	M&E Intensity	-1.07
	5.10		-0.33
R&D Intensity	-0.14	R&D Intensity	0.09
	-1.62		0.23
Adjusted R^2	0.84 *	Adjusted R^2	-0.27

Human Capital :	ln (average share of employees with university degrees)	Human Capital :	ln (average share of employees with university degrees)
M&E Intensity :	ln (M&E per employed person)	M&E Intensity :	ln (M&E/GDP)
R&D Intensity :	ln (R&D per employed person)	R&D Intensity :	ln (R&D/GDP)

Notes: * Statistically significant at the 1% level.
** Statistically significant at the 5% level.

DETERMINANTS OF INNOVATION

THE PREVIOUS SECTION HAS INVESTIGATED THE EXTENT to which labour productivity is determined by innovative activity, both internationally and across North American industries. In this section, we now turn to an analysis of the determinants of innovation with the aim of investigating what conditions support innovative activity.

FUNDAMENTAL INNOVATION

THE CREATION OF NEW TECHNOLOGIES, products and processes can be measured by either the outputs of the process, or its inputs. Output can be proxied by the number of patents granted per capita, or the number of patents in force per capita. The most common input proxies are R&D intensity (the ratio of R&D to GDP) and the human capital engaged in research (the share of R&D personnel in the total population). While none of these measures is a perfect indicator of fundamental innovation, there is a high degree of correlation between them (Figure 9). Countries with high R&D and human capital intensities, such as the United States, Japan and Sweden, also have high per capita fundamental innovation. On the other hand, countries with low R&D/GDP ratios and low human capital intensities, such as Hungary and Spain, exhibit low per capita fundamental innovation. Canada ranks slightly below the middle of these two extremes.

Our conceptual framework suggests that both fundamental and applied innovation are positively influenced by a number of important factors in the business environment, some of which have a more concrete relationship with innovation than others. The first two examined here, intellectual property protection and the strength of the domestic economy, directly affect the returns to innovative activity. The others — quality of financial services, openness of the domestic economy, quality of technological infrastructure and quality of management — have less direct effects on domestic innovation abilities.

The data on the quality of the business environment used to investigate the relationship between innovative output and the quality of the business climate, with the exception of intellectual property rights, come from the World Competitiveness Report (1999). This report rates the quality of specific conditions across 47 economies internationally, and uses the ratings to index and rank the economies for the general business conditions that support competitiveness in a number of ways. The index for intellectual property rights comes from a study by Park and Ginarte (1997) which scores a country's patent protection based on characteristics of the national patent regime.

In our empirical analysis, we find that both direct and indirect business conditions are positively and significantly correlated to fundamental innovation. Countries with strong intellectual property protection also have higher levels of R&D intensity (Figure 13) and of patents in force per capita, as do countries with stronger domestic economies (Figure 14). Countries with better technological infrastructure, as ranked by the World Competitiveness Index, also have higher R&D intensity and more patents in force (Figure 17). Surprisingly, a more general infrastructure measure, which includes both physical and environmental infrastructure, is more closely correlated with the two measures of fundamental innovation. The correlation between the general infrastructure indicator and R&D intensity is 0.72, and that between the general infrastructure and patents in force is 0.83, compared to only 0.70 and 0.68, respectively, for the technology infrastructure ranking. The degree of internationalization, or global links, is also positively correlated with the two indicators of fundamental innovation across developed and developing countries (Figure 15). Countries with better capital market performance and higher quality financial institutions also have higher levels of R&D intensity and more patents in force (Figure 16). A more specific measure on the availability of adequate financial resources for technological development has a stronger relationship with R&D intensity: the correlation between R&D intensity and financial resources for technology is 0.74.

While little can be said about the relative magnitude of variations in the direct and indirect determinants of fundamental innovation, the cross-country regression analysis provides some indication of the relative importance of each. Table 4 shows that the direct determinants can explain much more of the cross-country variation in fundamental innovation than the less direct variables. The two indicators of fundamental innovation, patents in force per 100,000 population and R&D as a percentage of GDP, were each regressed on the direct determinants of innovation, (R&D personnel per capita, intellectual property protection, and strength of the domestic economy), on the indirect determinants (internationalization, finance, technology infrastructure, and management), and on the direct and indirect determinants together.

In the all-encompassing Equation (1A), the adjusted R^2 is 0.72, but only R&D personnel per capita and the strength of patent rights are significant determinants of patent activity. Additionally, the signs for strength of the domestic economy and internationalization are positive — the opposite of what is expected for a ranked variable — but the t-statistics on these variables are very low. Equation (1B) regresses R&D intensity only on the direct determinants of innovation; the adjusted R^2 is 0.74, higher than in the all-inclusive Equation (1A). Again, only R&D personnel per capita and patent rights are significant; however, the sign for strength of the domestic economy is negative, as expected. The explanatory power of the less direct business environment factors, as a group, is significantly lower; the adjusted R^2 is only 0.47. Of these factors, only the strength of the technology infrastructure is a significant determinant of R&D intensity.

Similar results are obtained when regressing on the other measure of fundamental innovation, patents in force per 100,000 population. The combined explanatory power of both the innovation-specific factors and general business climate factors is high — the adjusted R^2 is 0.79. Again, only R&D personnel per capita and patent rights are significant determinants of fundamental innovation. When only the group of direct determinants is regressed upon, the adjusted R^2 does not fall significantly, and all three direct conditions affecting fundamental innovation are individually significant. However, when we regress patents in force on the indirect environmental conditions, the adjusted R^2 falls to 0.63. While this implies that the indirect factors are more important for the patent activity measure of fundamental innovation than for the R&D intensity measure, it also indicates that the indirect environmental conditions have much less explanatory power than the direct determinants of innovation. Within the group of business climate factors, the only individually significant variable is, again, the strength of the technological infrastructure.

The implication of these findings is that Canada's fundamental innovation performance can be enhanced, with the best results, by improving Canada's performance on innovative inputs and business climate conditions directly related to innovation. The World Competitiveness Report rankings indicate that Canada has plenty of scope for improvement in these areas. (Box 1)

BOX 1

BUSINESS ENVIRONMENT MEASURE, 1999	CANADA'S RANKING (OUT OF 47)
Internationalization[1]	24th
R&D Personnel per Capita	16th
Technology Infrastructure	6th
Finance	11th
Financial Resources for Technology Improvement	14th
Strength of the Domestic Economy	12th
	(OUT OF 120)
Intellectual Property Rights	27th

Note: [1] In spite of Canada's high trade openness, it ranks low on the internationalization measure partly because of its poor export market diversification (a heavy reliance on the U.S. market), large current account deficit, lower share of total trade made up by commercial services, and slower growth of foreign direct investment (FDI) relative to the other countries ranked.

APPLIED INNOVATION

APPLIED INNOVATION IS CLOSELY RELATED to fundamental innovation. The two measures of fundamental innovation — use of specialized robots in manufacturing and Internet users per capita — are both positively correlated with R&D intensity across OECD countries (Figure 10). Countries that use more advanced technologies also devote more resources to R&D.

Additionally, they have a stronger performance on other measures of innovation inputs. The use of both advanced technologies is also positively correlated with high levels of human capital, measured by the number of researchers in the labour force (Figure 11). Countries with a high proportion of researchers in the labour force also use more robots in manufacturing and have high Internet usage. Similarly, applied innovation is positively related to higher rates of physical investment in related capital (Figure 12). The use of specialized robots is high in countries where a high proportion of GDP is invested in machinery and equipment. Likewise, Internet usage is high in countries that invest a high proportion of GDP in information and communications technologies (ICT).

Further evidence on the relationship between applied innovation and the conditions for fundamental innovation in OECD countries comes from the multiple regression analysis reported in Table 5. The log of Internet users per 1000 population has been regressed on ICT investment intensity, researchers per capita, and R&D intensity. The overall regression is significant, with an adjusted R^2 of 0.37. Of the innovation conditions, only ICT investment is a significant determinant of Internet use independent of the other innovative inputs. Additional tests of joint significance (not reported) show that the number of researchers per capita contributes to the explanation of Internet use per capita, but that R&D intensity does not. This means that applied innovation is affected most strongly by innovative inputs that improve an economy's ability to adopt applied innovation, but that fundamental innovation in the form of R&D intensity plays a small part in determining the use of applied innovation.

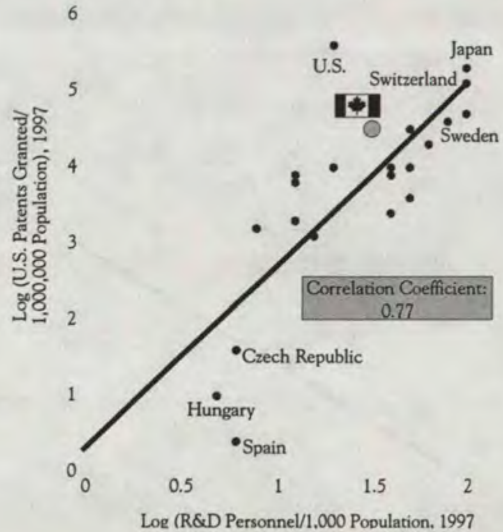
Finally, there is limited evidence on the relationship between applied innovation and business climate conditions. The quality of the financial service industry is positively correlated with the applied innovation measure of Internet use, showing a correlation of 0.52. The rank correlation between technological infrastructure and Internet use is 0.59, while that between technological infrastructure and the use of robots is 0.31. Management quality is also positively associated with the applied innovation measure of Internet use, with a correlation of 0.72.

In short, innovation is driven by a number of important factors: R&D intensity, investment in M&E, human capital, technological infrastructure, intellectual property protection, strength of the domestic economy, quality of financial institutions and quality of management.

FIGURE 9

R&D INTENSITY AND U.S. PATENTS GRANTED PER CAPITA, OECD COUNTRIES

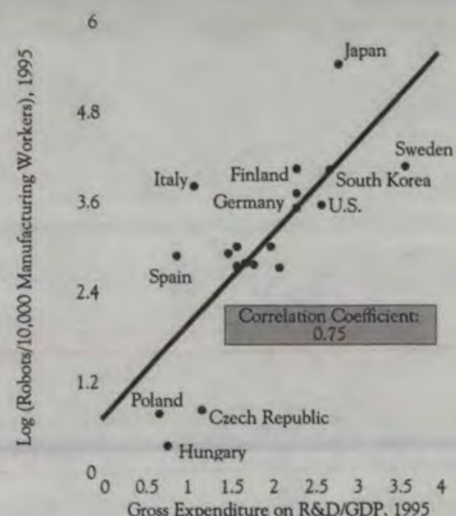
R&D PERSONNEL PER CAPITA AND U.S. PATENTS GRANTED PER CAPITA, OECD COUNTRIES



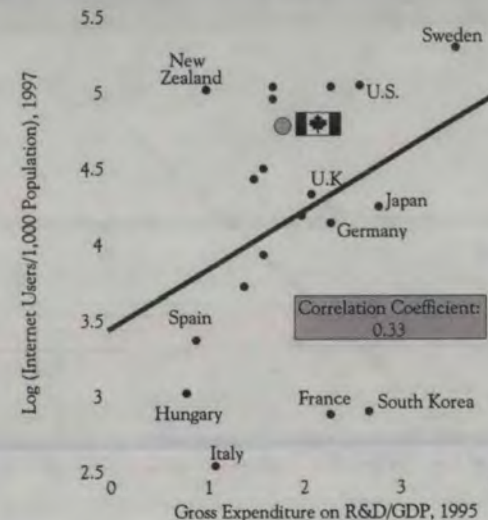
Source: Industry Canada compilations based on unpublished data from the U.S. Patent and Trademark Office and the OECD.

FIGURE 10

USE OF SPECIALIZED ROBOTS IN MANUFACTURING* AND R&D INTENSITY, OECD COUNTRIES



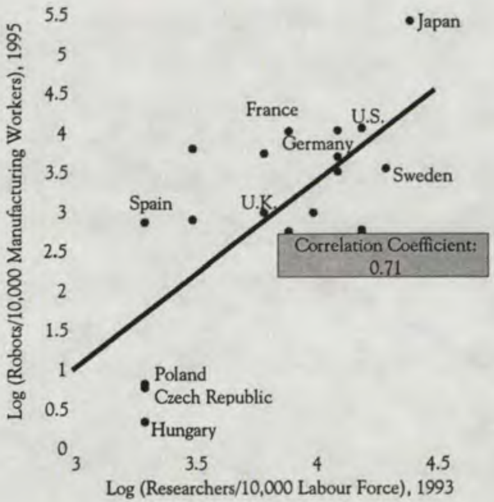
INTERNET USE AND R&D INTENSITY, OECD COUNTRIES



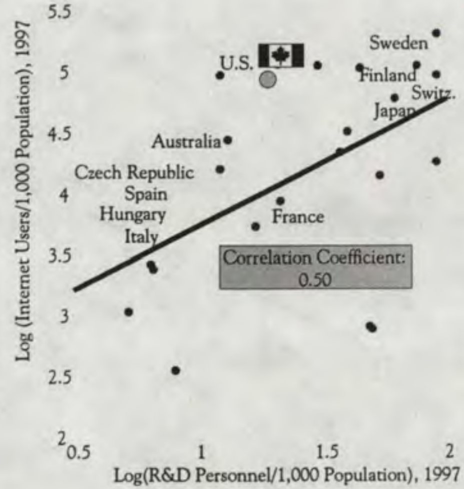
Note: * Number of trajectory operated and adoptive robots.
Source: Industry Canada compilations based on data from the OECD, *World Industrial Robots 1996*, and the International Telecommunication Union.

FIGURE 11

USE OF SPECIALIZED ROBOTS IN MANUFACTURING* AND HUMAN CAPITAL INTENSITY IN OECD COUNTRIES



INTERNET USE AND HUMAN CAPITAL IN OECD COUNTRIES

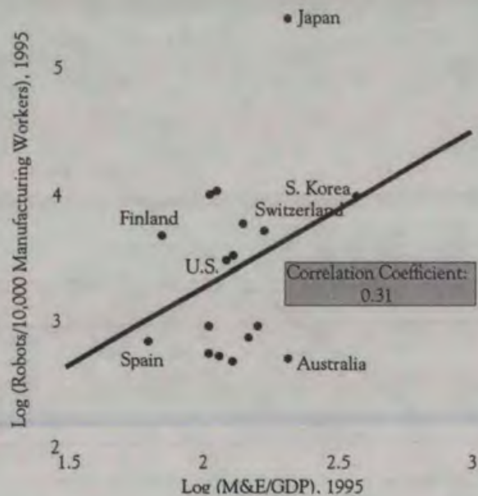


Note: * Number of trajectory operated and adoptive robots.

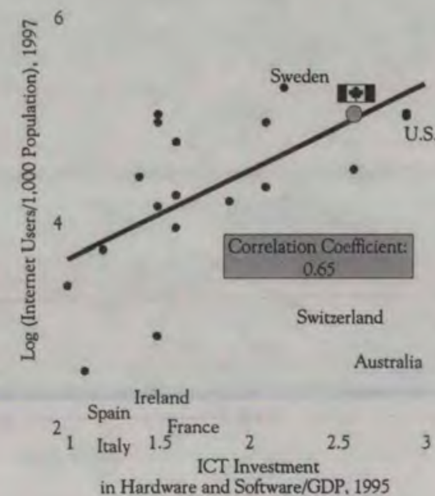
Source: Industry Canada compilations based on data from the OECD, *World Industrial Robots 1996*, and the International Telecommunication Union.

FIGURE 12

USE OF SPECIALIZED ROBOTS IN MANUFACTURING* AND M&E INTENSITY IN OECD COUNTRIES



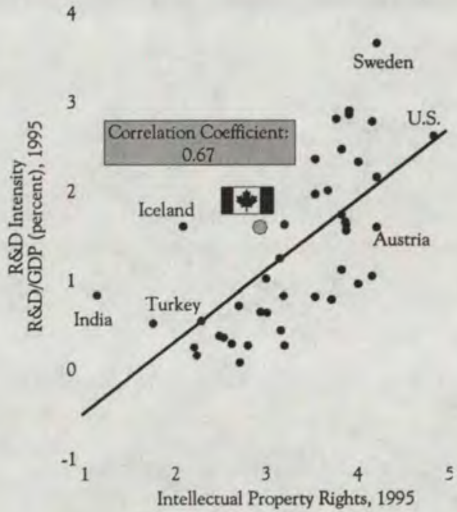
INTERNET USE AND ICT INVESTMENT, OECD COUNTRIES



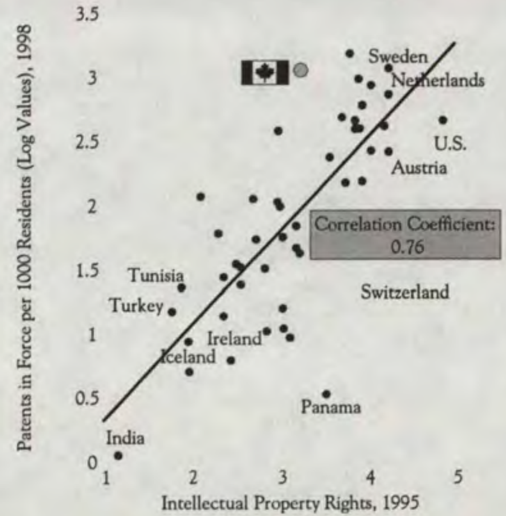
Note: * Number of trajectory operated and adoptive robots.
Source: Industry Canada compilations based on data from the OECD, *World Industrial Robots 1996*, and the International Telecommunication Union.

FIGURE 13

R&D INTENSITY AND INDEX OF INTELLECTUAL PROPERTY RIGHTS



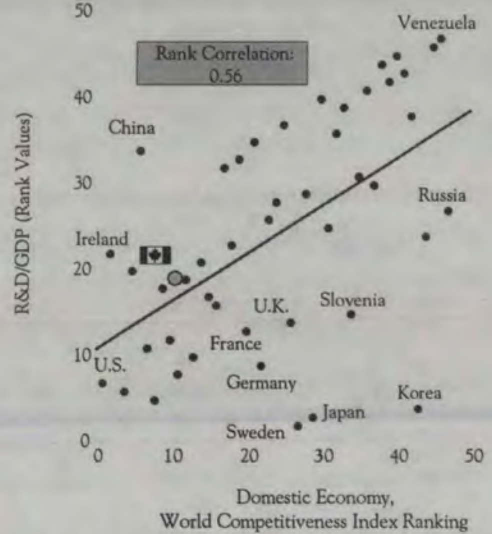
PATENTS IN FORCE PER CAPITA AND INDEX OF INTELLECTUAL PROPERTY RIGHTS



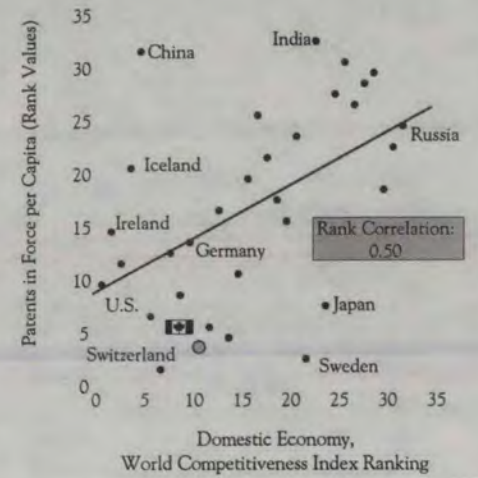
Source: *World Competitiveness Yearbook*, 1999, and Park and Ginarte, 1997.

FIGURE 14

STRENGTH OF THE DOMESTIC ECONOMY AND R&D INTENSITY, 1999



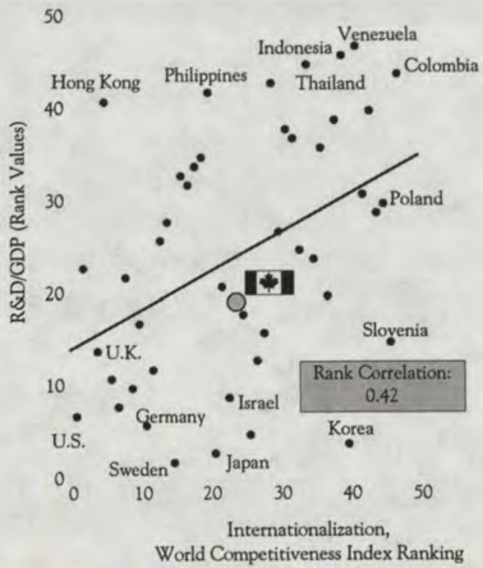
STRENGTH OF THE DOMESTIC ECONOMY AND PATENTS IN FORCE, 1999



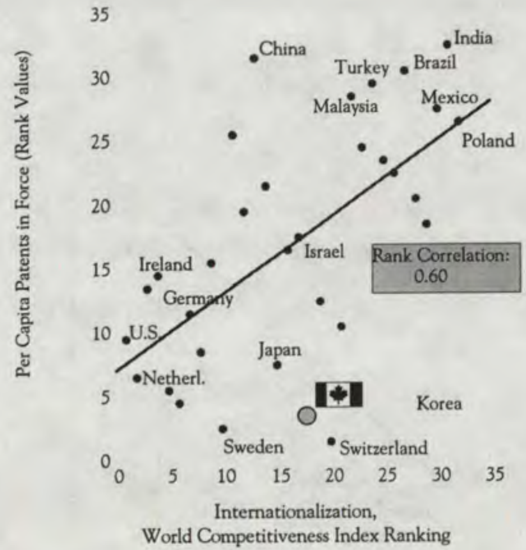
Source: *World Competitiveness Yearbook*, 1999.

FIGURE 15

INTERNATIONALIZATION AND R&D INTENSITY, 1999



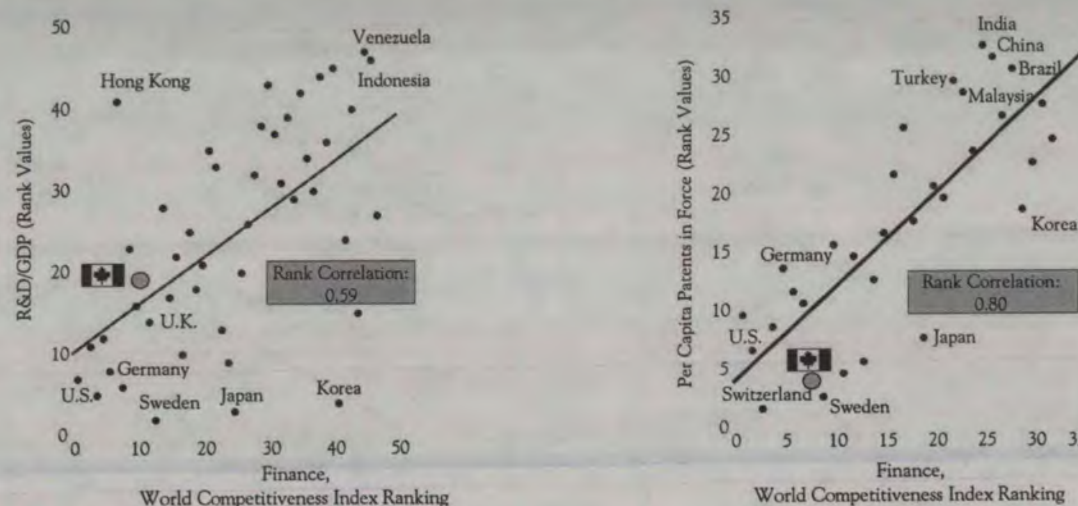
INTERNATIONALIZATION AND PATENTS IN FORCE, 1999



Source: *World Competitiveness Yearbook*, 1999.

FIGURE 16

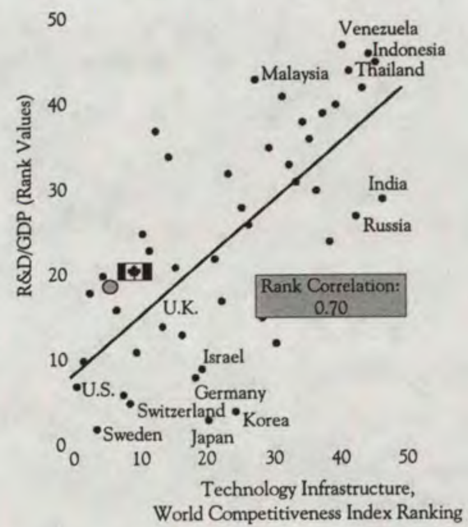
FINANCE AND R&D INTENSITY, 1999 | FINANCE AND PATENTS IN FORCE, 1999



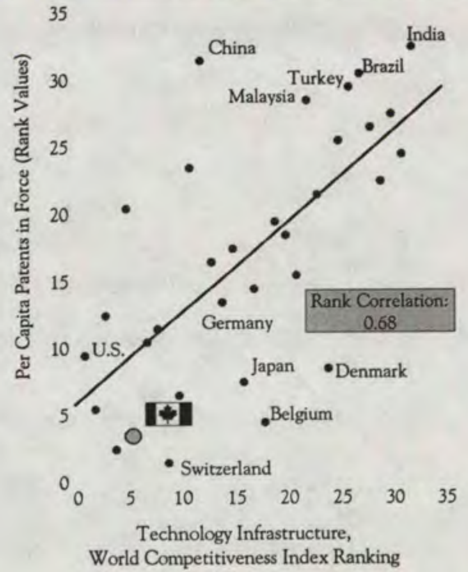
Source: *World Competitiveness Yearbook*, 1999.

FIGURE 17

TECHNOLOGY INFRASTRUCTURE AND R&D INTENSITY, 1999



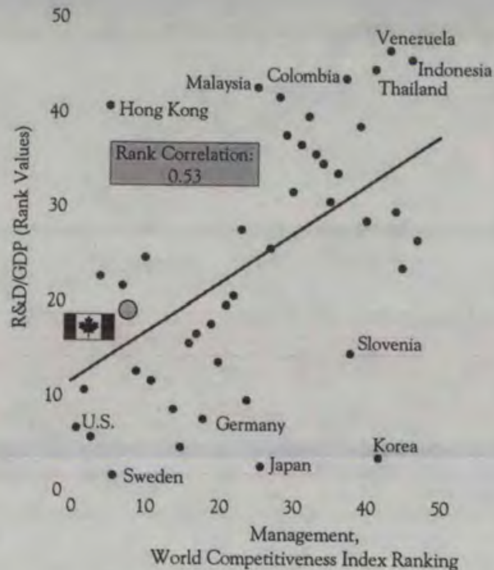
TECHNOLOGY INFRASTRUCTURE AND PATENTS IN FORCE, 1999



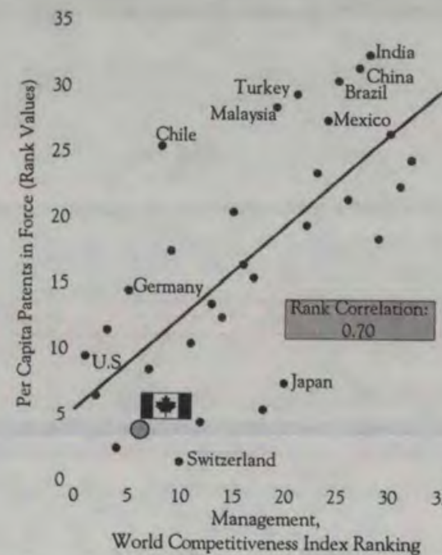
Source: *World Competitiveness Yearbook*, 1999.

FIGURE 18

MANAGEMENT AND R&D INTENSITY, 1999



MANAGEMENT AND PATENTS IN FORCE, 1999



Source: *World Competitiveness Yearbook*, 1999.

TABLE 4

FUNDAMENTAL INNOVATION: CROSS-COUNTRY EVIDENCE, 1999

	EQUATION 1 DEPENDENT VARIABLE: R&D INTENSITY = (R&D/GDP*100)				EQUATION 2 DEPENDENT VARIABLE: LN (PATENTS IN FORCE PER 100,000 POPULATION)		
	1A	1B	1C		2A	2B	2C
Intercept	-0.15	-0.51	2.51 ***	Intercept	1.33 **	0.56	3.33 ***
	-0.23	-1.15	10.61		2.45	1.56	17.89
R&D Personnel per Capita	0.24 ***	0.25 ***		R&D Personnel per Capita	0.09 **	0.09 ***	
	5.07	6.11			2.60	2.79	
Intellectual Property Rights	0.27 *	0.33 ***		Intellectual Property Rights	0.32 **	0.47 ***	
	1.91	2.88			2.67	5.05	
† Domestic Economy	0.01	0.00		† Domestic Economy	0.01	-0.02 **	
	0.70	-0.35			0.61	-2.19	
† Internationalization	0.00		-0.01	† Internationalization	0.00		-0.02
	0.37		-0.65		-0.29		-1.63
† Finance	-0.01		-0.02	† Finance	-0.01		-0.02
	-0.54		-1.12		-0.84		-1.08

TABLE 4 (CONT'D)

	Equation 1 Dependent Variable: R&D Intensity = (R&D/GDP*100)				Equation 2 Dependent Variable: ln (Patents in Force per 100,000 Population)		
	1A	1B	1C		2A	2B	2C
† Technology	0.00		-0.04 ***	† Technology	-0.02		-0.04 ***
In frastructure	-0.45		-2.96	Infrastructure	-1.44		-2.96
† Management	-0.01		0.02	† Management	-0.01		0.01
	-0.37		0.94		-0.44		0.70
Adjusted R^2	0.72 ***	0.74 ***	0.47 ***	Adjusted R^2	0.79 ***	0.77 ***	0.63 ***

Notes: * Statistically significant at the 10% level.
** Statistically significant at the 5% level.
*** Statistically significant at the 1% level.
† Note that domestic economy, internationalization, finance, technology infrastructure and management are rank indexes, with the strongest country ranked at 1. Thus, the expected signs of the coefficients are negative.

TABLE 5

APPLIED INNOVATION: CROSS-COUNTRY EVIDENCE, 1997

	EQUATION 1 DEPENDENT VARIABLE: LN (INTERNET USERS PER 1,000 POPULATION)
Intercept	2.12 **
	3.10
ICT Investment/GDP	0.72 *
	2.70
Log (Researchers/1,000 population)	0.33
	0.57
R&D/GDP	0.19
	0.63
Adjusted R^2	0.37 **

Notes: * Statistically significant at the 1% level.
** Statistically significant at the 5% level.

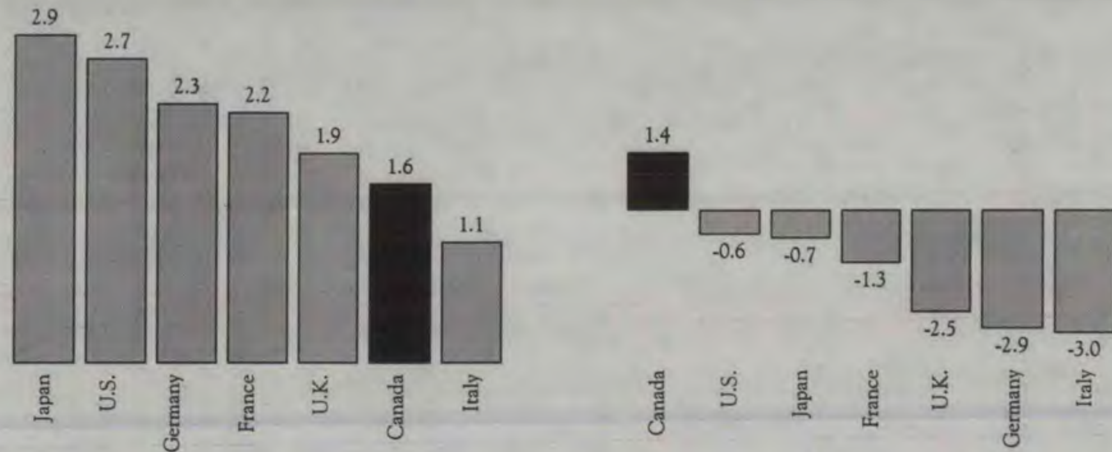
CANADA'S INNOVATION PERFORMANCE: G-7 COMPARISONS

THE LEVEL OF INNOVATION IN CANADA lags behind the United States for most of the key indicators, and it lags behind other G-7 economies for many (Figures 19 to 25). Canada's gross domestic expenditure on research and development is below that of all G-7 countries, with the exception of Italy. Canadians hold a much lower number of U.S. patents per capita than the Americans or the Japanese. Similarly, Canada's expenditure on M&E as a percentage of GDP is the lowest among the G-7 countries. However, Canada's performance is better when investment in ICT as a percentage of GDP is compared across the G-7; Canada ranks third on this measure, just below the United States. Furthermore, Canada has a higher proportion of R&D personnel than the United States, but still only ranks 4th in the G-7.[1]

FIGURE 19

GROSS DOMESTIC EXPENDITURE ON R&D GERD/GDP, 1997 (PERCENT)

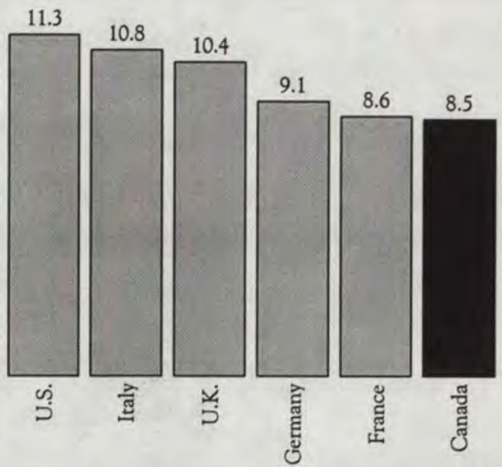
AVERAGE ANNUAL GROWTH OF GERD/GDP RATIO, 1990-97 (PERCENT)



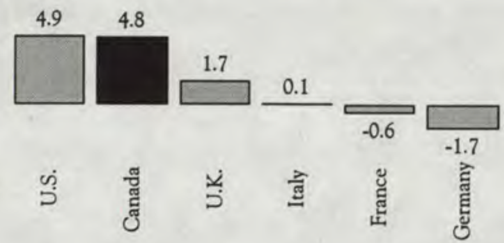
Source: Industry Canada compilations using data from the EAS (MSTI Database), OECD, April 1999, and *Science, Technology and Industry Outlook 1998*.

FIGURE 20

REAL INVESTMENT IN MACHINERY AND EQUIPMENT M&E/GDP, 1998
(PERCENT)



AVERAGE ANNUAL GROWTH OF REAL M&E/GDP RATIO, 1990-98
(PERCENT)

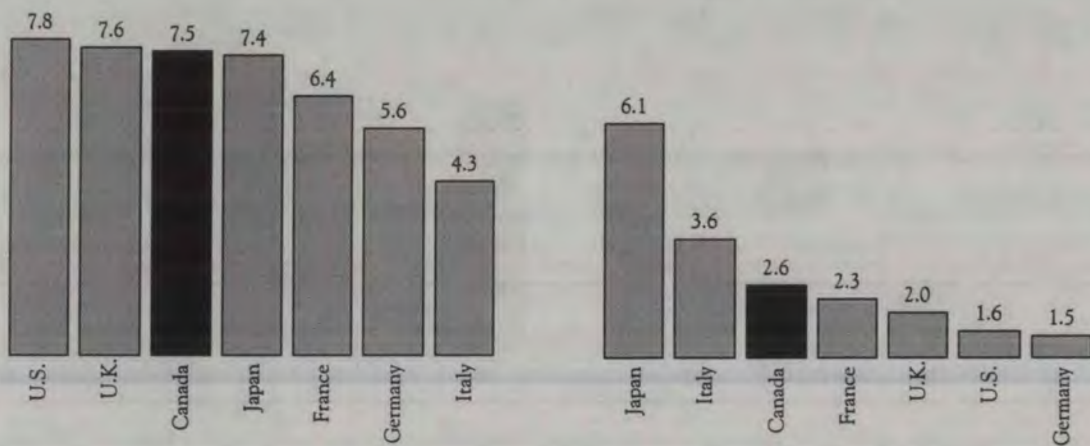


Note: Japan was excluded from G-7 due to a lack of comparable data.
Source: Industry Canada compilations using data from the OECD.

FIGURE 21

ICT EXPENDITURE ON HARDWARE, SOFTWARE AND TELECOMMUNICATIONS, 1997 (PERCENT OF GDP)

AVERAGE ANNUAL GROWTH OF SHARE OF ICT EXPENDITURE ON HARDWARE, SOFTWARE AND TELECOMMUNICATIONS IN GDP, 1992-97 (PERCENT)

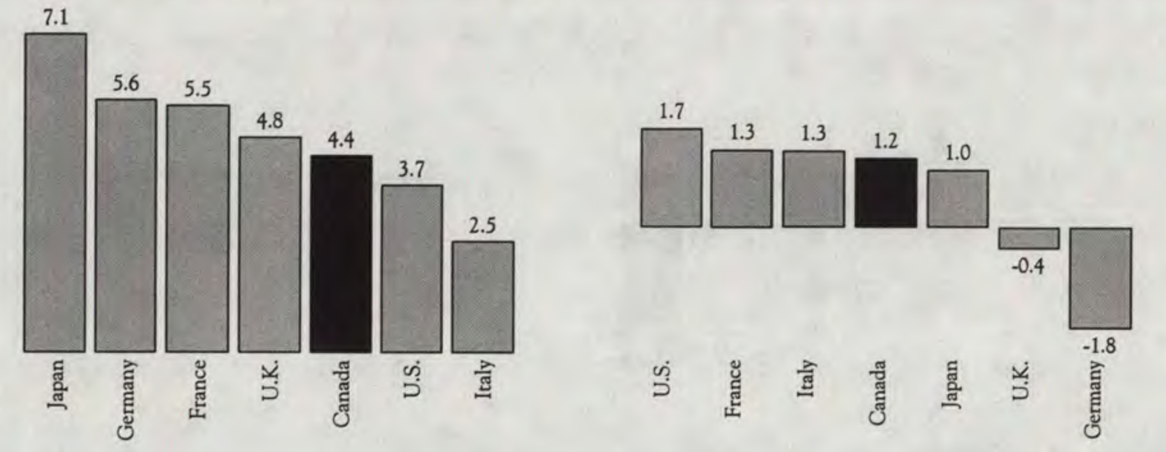


Source: Industry Canada compilations based on *Science, Technology and Industry Scoreboard 1999*, OECD, and data obtained from the ADB database and the World Information Technology Services Alliance (WITSA)/International Data Corporation (IDC), 1998.

FIGURE 22

R&D PERSONNEL NATIONWIDE PER CAPITA, 1997 (FULL-TIME WORK EQUIVALENT, '000S)

AVERAGE ANNUAL GROWTH OF R&D PERSONNEL NATIONWIDE PER CAPITA, 1989-97 (PERCENT)

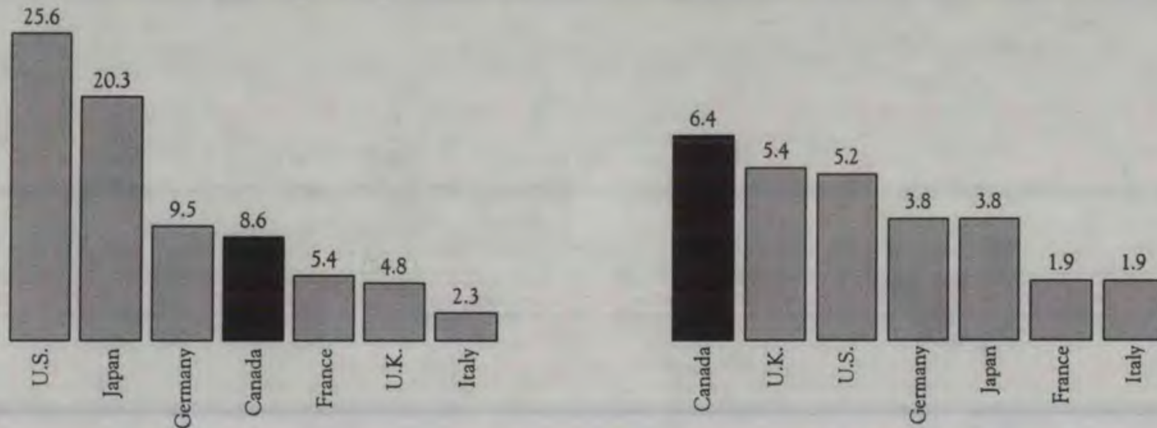


Source: Industry Canada compilations using data from *Science, Technology and Industry Outlook 1998*, OECD.

FIGURE 23

AVERAGE U.S. PATENTS GRANTED TO FOREIGNERS, 1992-97
(PER 100,000 POPULATION)

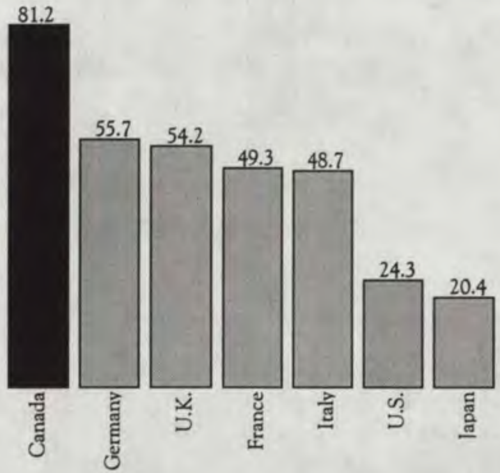
AVERAGE ANNUAL GROWTH OF U.S. PATENTS GRANTED, 1992-97
(PERCENT)



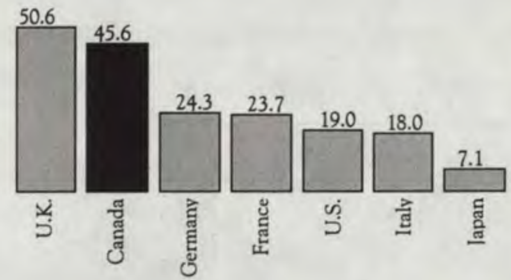
Source: Trajtenberg (2002).

FIGURE 24

EXPORTS PLUS IMPORTS OF GOODS AND SERVICES/GDP, 1998 (PERCENT)



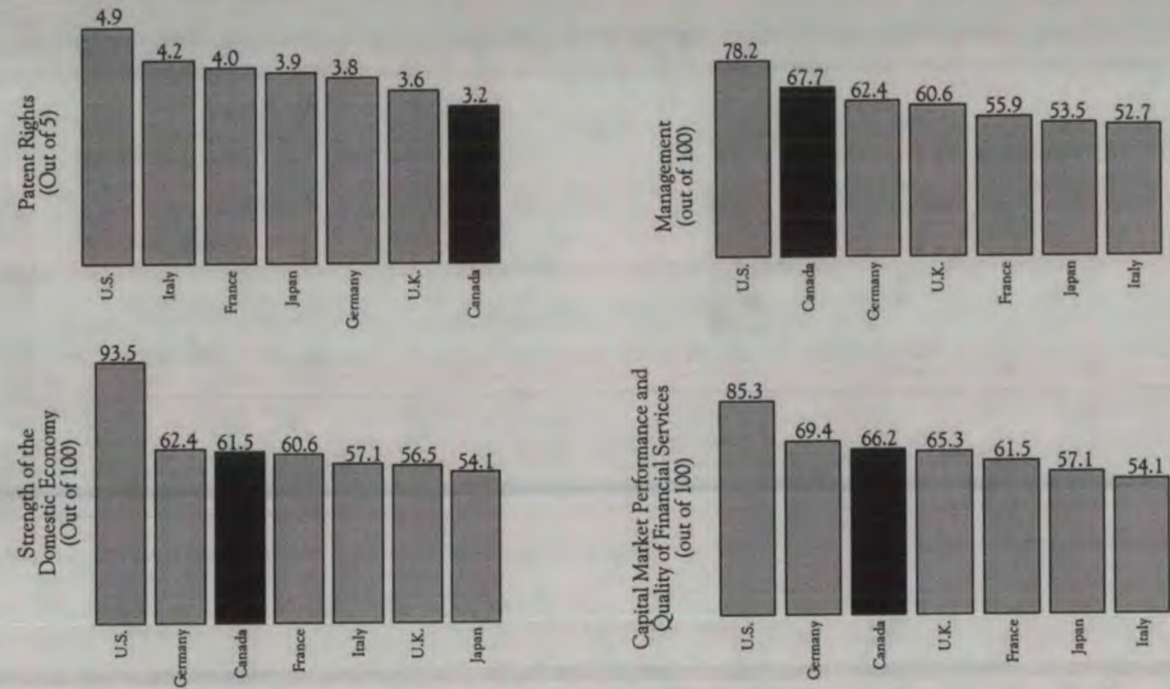
INWARD AND OUTWARD FDI STOCK/GDP, 1997 (PERCENT)



Source: Industry Canada compilations using data from the OECD and the *World Investment Report 1999, Foreign Direct Investment and the Challenge of Development*, United Nations.

FIGURE 25

BUSINESS CLIMATE INDICATORS IN THE G-7, 1999



Source: *The World Competitiveness Yearbook*, 1999, and Park and Ginarte, 1997.

There is some evidence that Canada's innovation levels are catching up with the United States and other G-7 economies. The innovation gap measured by GERD/GDP has narrowed between 1990 and 1997. Canada's R&D intensity grew at 1.4 percent per annum, while the other G-7 economies experienced a decline. Similarly, M&E intensity grew faster here than in all other G-7 economies, except the United States, and Canada was tied with Italy for the fastest growing ICT intensity. In addition, Canada experienced the fastest average annual percentage growth in U.S. patents granted between 1992 and 1997. However, Canada ranked behind the United States, France and Italy for the average annual percentage growth of R&D personnel per capita. Overall, the slow convergence of innovation indicators between Canada and the rest of the G-7 bodes well for our future productivity performance.

Another mitigating factor is Canada's openness to international trade and investment. With a lower capacity for domestic fundamental innovation than most of the G-7 countries, it is important that Canada be open to the diffusion of innovation and knowledge developed elsewhere. In this respect, Canada has the highest level of trade openness of any G-7 country, and is second only to the United States in FDI openness. However, Canada's international linkages are dominated by its economic relations with the United States. Further, Canada badly trails the United States on all the key determinants of a healthy business climate: intellectual property protection, strength of the domestic economy, quality of financial institutions and quality of management.

CONCLUSION

OUR EMPIRICAL FINDINGS SUGGEST that innovative activity (as measured by the number of patents granted) is highly and positively related to productivity and per capita income across developed and developing countries. Similarly, in manufacturing industries, productivity *levels* are positively correlated with three key drivers of innovation (R&D intensity, human capital intensity and M&E intensity) in Canada as in the United States. However, productivity *growth* is not significantly correlated with these variables. Further, of the three key drivers of innovation, M&E investment intensity provides the strongest boost to productivity levels.

Across countries, fundamental innovation (measured by the number of patents granted per capita) is positively related to R&D spending and human capital. Similarly, applied innovation (proxied by the use of advanced technologies) is positively influenced by R&D spending and investments in human capital and M&E. Both types of innovative activities are also conditioned by factors that shape the general business climate: intellectual property rights, macro-economic conditions, global links, adequacy of the financial services infrastructure and quality of management. However, it has been determined that, by far, the most effective means of promoting innovation is to focus on the technology sector specific conditions that directly influence innovation.

Canada lags seriously behind the United States, our largest trading partner and main competitor in terms of investment, R&D, skilled people and high value-added activities for the three key drivers of innovation: R&D, M&E, and human capital. Canada also lags behind the United States for all the key determinants of a healthy business climate. However, Canada has made significant progress in the 1990s in closing the R&D gap. Furthermore, Canada leads the United States in terms of openness, an important pre-condition for an innovative economy (Harris, 2002).

These findings strongly suggest that in order to improve its competitive position and close the gap in productivity and real incomes, Canada needs to make up its R&D, M&E and human capital shortfall, and to improve the general business climate vis-à-vis the United States.

ENDNOTE

1 However, Canada ranks 6th in the G-7 for total R&D personnel in business per capita, only ahead of the United Kingdom.

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11

The Economic Determinants of Innovation

SUMMARY

This paper describes what economists know, suspect, and guess about the underlying determinants of innovation. It evaluates the evidence and points out areas where further work is urgently needed. In many cases, no solid conclusions can be drawn. Though the reader may find this frustrating, knowing "what we don't know" is the beginning of wisdom, and also a guide to avoiding public policy gaffes.

A few general facts about innovation are relatively clear. Countries that show more evidence of innovation are richer and grow faster. Companies that show more evidence of innovation post better financial performance and have higher share prices. These broad findings seem quite robust, and justify the current focus of both public policy-makers and corporate decision-makers on fostering innovation.

In a knowledge-based economy, the primary competition is competition to innovate first, not competition to cut prices as standard economics posits. Because sole ownership of an innovation bestows monopoly power, the economic laws of perfect competition do not govern innovators. Their monopolies reward their investment in innovation. But unlike monopolies in standard economic theory, innovation-based monopolies are temporary, for they last only until another innovator makes yesterday's innovation obsolete.

Intellectual property rights prolong innovators' monopolies. Do they encourage more innovation by increasing the economic rewards to successful innovators? Or do they slow innovation by letting yesterday's winners rest on their laurels? Economic theorists have generally assumed the former view, but recent empirical studies seem more consistent with the latter.

Larger firms clearly have an advantage in some types of innovations where large amounts of equipment are required. In general, such capital-intensive

research is found in work aimed at modifying, extending, or refining previous innovations. Radical innovations are associated with smaller firms.

Since large firms are required to mobilize the capital needed for much innovation, monopoly problems become an issue. This is one reason why liberalized international trade and capital flows are required in an innovation-based economy. Global markets make monopolies more difficult to establish and maintain, but also allow firms to achieve economies of scale in research funding.

Small firms appear to be at an advantage in producing breakthrough, radical innovations. This raises the issue of whether state support for small firms might encourage such innovations. The evidence does not support this. Industrial policies of this sort seem prone to failure because they invite "rent-seeking" and so end up fostering and subsidizing losers. Firms rationally become innovative at extracting money from governments because that is where the highest return is. Government policy in this area must take care to keep corporations' returns to political lobbying lower than their returns to real innovation.

In general, this means subsidizing firms makes much less sense than subsidizing infrastructure or education, though government failure problems must be kept in check regardless. One consistent finding is that innovation raises the demand for high-skill workers and drives up their wages. Governments should also realize that lower taxes, both personal and corporate, are the simplest and most direct way to subsidize winners rather than losers.

There is a large literature on the tendency of innovative firms to spontaneously form geographical clusters. Although a number of high-profile theories have been proposed to explain this, the data seem most consistent with concentrations of skilled workers attracting the firms that need them, and with those firms attracting more skilled workers, in a positive feedback loop. If so, concentrated pools of skilled labour would seem to underlie cluster formation.

One theory of this ilk, due to Jacobs (1969), appears most strongly supported by the data. It stresses the importance of the cross-industry transfer of ideas, and implies that one-industry clusters like Silicon Valley and Detroit are less stable than more diversified clusters, like Boston, New York, or London. This suggests that highly focused "centers of excellence" might produce only limited innovation.

Corporate governance also seems to matter. Many of the classical capital budgeting tools used by corporate managers work poorly in assessing the returns to innovation. Newer techniques that might be more appropriate are being developed, but are not applied in Canada to any significant extent.

Incentive schemes and corporate intellectual property rights systems that let innovative employees own stakes in their innovations appear to foster "basic research" within corporations. Presumably, corporate scientists know what basic work is needed to pursue financially rewarding applied research later.

Promising people a high monetary reward for valuable innovations seems superior to having government committees or corporate managers screen and approve funding proposals for basic or applied research.

Excessive equality may thus be a problem. Studies of Sweden's current dramatic economic problems show clearly that high taxes and job security reduced worker productivity. High personal taxes also kept the pay of skilled workers low and so increased the demand for skilled workers. But the same low wages discouraged the next generation from acquiring skills. Sweden's productivity is low, its skill shortage serious and its economy faltering.

But excessive inequality is also a problem. Countries where established wealthy families control most firms have low rates of innovation. Established wealthy families are content with the status quo, and therefore are understandably unenthusiastic about innovation. Many traditional Canadian policies have the perhaps unintended effect of protecting inherited wealth. These include Canada's high income taxes (which deter the formation of rival concentrations of wealth), low taxes on inherited wealth (which preserve existing wealth concentrations), and a tradition of protectionism (which protects established firms from competition).

Culture also matters. Tradition-bound, class-conscious societies with hierarchical revealed religions are statistically associated with serious economic problems. In such cultures, the elite views business laws that protect entrepreneurs with suspicion. Economic relationships are often confined to relatives and close friends because no legal or cultural penalties enforce business contracts with strangers. Outsiders defeating established power is part of the American cultural mythology. Perhaps government should subsidize American culture and its mythic ideal of "enterprise".

Finally, financial development clearly matters. A competitive financial system helps innovative small players grow quickly and displace established wealth. Large, independent and scientifically sophisticated venture capital funds seem critical in this context.

WHAT IS INNOVATION?

UNTIL VERY RECENTLY, INNOVATION WAS A DIRTY WORD. As the quote from the Oxford English Dictionary (OED) in Figure 1 shows, the use of the word in English had strongly negative connotations from the 16th century into the 19th century. An innovation was a rebellious, troublesome and useless trifling with established correct practices. The OED attributes the first use of the word innovation in its modern sense, of a useful and creative change, to the economist Josef Schumpeter in 1939.

FIGURE 1

THE CHANGE OVER TIME FROM A NEGATIVE TO A POSITIVE CONNOTATION OF THE WORD "INNOVATION"

innovation [ad. L. innovation-em, n. of action f. innovare to innovate, f. L. innovat-, ppl. stem of innovare to renew, alter, f. in- (in-2) + novare to make new, f. novus new. Cf. Fr. innover (1322 in Godef. Compl.): cf. Fr. innovation (1297 in Hatz.-Darm.).]

1. a). The action of innovating; the introduction of novelties; the alteration of what is established by the introduction of new elements or forms. T. Norton, Calvin's Inst. Table Contents, "It is the duty of private men to obey, and not to make innovation of states after their own will." 1597; Hooker, Eccl. Pol. v. xlii. 11. "To traduce him as an authour of suspitious innouation." 1639; Webster, Appius V. v. iii, "The hydra-headed multitude that only gape for innovation." 1796; Burke, Corr. (1844) III. 211. "It is a revolt of innovation; and thereby, the very elements of society have been confounded and dissipated."

1. b). Revolution (= L. nov res). (Obs.) 1596; Shaks., 1 Hen. IV, v. i. 78. "Poore Discontents, Which gape, and rub the Elbow at the newes of hurly burly Innouation."

2. a). A change made in the nature or fashion of anything; something newly introduced; a novel practice, method, etc. 1548; Act 2 3 Edw. VI, c. 1. "To staye Innovacions or newe rites." 1641; (title). "A Discovery of the notorius Proceedings of William Laud, Archbishop of Canterbury, in bringing Innovations into the Church." 1800; Asiatic Ann. Reg., Misc. Tr. 106/1. "The tribute you demand from the Hinds ... is an innovation and an infringement of the laws of Hindustn." A. 1862; Buckle, Civiliz. (1873) II. viii. 595. "To them antiquity is synonymous with wisdom, and every improvement is a dangerous innovation."

2. b). A political revolution; a rebellion or insurrection. (= L. nov res.) (Obs.) 1601; R. Johnson, Kingd. Commw. (1603) 227. "Neither doth he willingly arme them for feare of sedition and innovations." 1726; Leoni, Alberti's Archit. I. 77/2. "A Province so inclined to tumults and innovations."

3. (spec.) in (Sc. Law). The alteration of an obligation; the substitution of a new obligation for the old: 1861; W. Bell, Dict. Law Scot. 450/1. "Innovation, is a technical expression, signifying the exchange, with the creditor's consent, of one obligation for another; so as to make the second obligation come in the place of the first, and be the only subsisting obligation against the debtor, both the original obligants remaining the same."

4. (Bot.) The formation of a new shoot at the apex of a stem or branch; (esp.) that which takes place at the apex of the thallus or leaf-bearing stem of mosses, the older parts dying off behind; also (with pl.) a new shoot thus formed.

5. (Comm.) The action of introducing a new product into the market; a product newly brought on to the market. 1939; J. A. Schumpeter, Business Cycles I. iii. 84. "Innovation is possible without anything we should identify as invention, and invention does not necessarily induce innovation." 1958; J. Jewkes, et al. Sources of Invention ix. 249. "It seems impossible to establish scientifically any final conclusion concerning the relation between monopoly and innovation." 1962; E. M. Rogers, Diffusion of Innovations v. 124. "It matters little whether or not an innovation has a great degree of advantage over the idea it is replacing. What does matter is whether the individual perceives the relative advantage of the innovation." 1967; J. A. Allen, Sci. Innovation Industr. Prosperity ii. 8. "Innovation is the bringing of an invention into widespread, practical use.... Invention may thus be construed as the first stage of the much more extensive and complex total process of innovation."

6. innovation trunk, a kind of wardrobe trunk.

Hence: *innovational* of, pertaining to, or characterized by innovation; also in (Comm.)

innovationist one who favours innovations. 1800; W. Taylor, in Monthly Mag. VIII. 684. "Writers, who bring against certain philosophic innovationists a clamorous charge of Vandalism." 1817; Bentham, Plan Parl. Reform Introd. 194. "A proposition so daring, so innovational." 1873; R. Black, tr. Guizot's France II. xxv. 492. "His kingly despotism was new, and, one might almost say, innovational." 1959; J. P. Lewis, Business Conditions Analysis v. xxiv. 534. "The insights of economics do not illuminate the process of innovation very much.... On the optimistic side of the innovational outlook, it can be argued, [etc.]." 1960; L. S. Silk, Research Revolution iii. 50. "In the past, the United States has had three great innovational pushes."

The positive connotation of innovation, as a valuable improvement, is itself a new idea. This neatly illustrates the ambiguity that underlies the role of innovation in society. Schumpeter's concept of innovation as "creative destruction" highlights this ambiguity: Creative firms bring new products or better technology into the economy, but this destroys stagnant firms. This destruction is the downside of innovation.

New ideas, new applications, and new solutions to old problems are thus economically unsettled and untidy concepts. Over the past few centuries, rationalism and science have immeasurably improved life in the industrial democracies. We therefore rightly associate innovation with scientific, economic, and social progress. But the economic dualism remains. Just as farm hands were economic casualties of agricultural mechanization in the 1930s, assembly line workers may be the economic casualties of our age. The yin and yang of creative destruction abide.

In this paper, we describe what economists know, suspect, and guess about the underlying determinants of the pace of innovation. We will describe and evaluate the evidence as we go, and also point out areas where further work is urgently needed. In many cases, no solid conclusions can be drawn. Though the reader may find this frustrating, recognizing "what we don't know" is the beginning of wisdom, and also a guide to avoiding public policy gaffes.

Measuring Innovation

Before we examine the evidence bearing upon possible determinants of innovation, we must clarify that we are talking about measurable aspects of innovation only. Philosophical, literary, or other more abstract dimensions of innovation are not susceptible to economic analysis, and so must remain beyond the scope of this study, despite their importance.

The empirical literature on innovation most often uses one or more of three quantitative measures of innovative activity. None of these measures is perfect, and the flaws of each are discussed below. However, all three tend to produce concordant results on most issues when the researchers are careful to construct their statistical tests in ways that control for obvious biases and confounding correlations. These three measures are described below.

Research & Development Spending

Corporate R&D is widely used as a measure of a firm's investment in innovation. Since this number must be disclosed in annual reports by U.S. firms with nontrivial R&D budgets, many years of data are available for several thousand companies. These data are easy to obtain in computer readable form from Standard and Poor's Compustat division.

Unfortunately, R&D spending is harder to study in Canada, where R&D spending disclosure is not mandatory. This may let some Canadian firms hide their intense R&D spending from competitors. Or it may let backward looking Canadian firms hide their lack of R&D spending from public investors, who would demand more — for we know that when U.S. firms unexpectedly raise their R&D budgets, shareholder buying pushes up their stock prices (see Chan et al., 1990). We can infer which effect is more dominant, for R&D data is available from corporate tax records, and aggregate figures can be studied without violating the confidentiality of tax files. Gu and Whewell (1999) report that the industrial sector in Canada spent only 0.99 percent of GDP on R&D in 1997. The comparable figures for the United States and Japan are 1.96 and 2.01 percent, respectively.[1] Confidentiality about R&D spending would seem to be about hiding a lack of R&D from Canadian investors.

The main methodological criticism of using R&D spending is that it measures an input to innovation, not the number or value of the innovations actually produced. We know that firms often invest money in unprofitable capital projects, so the possibility that most R&D spending might be wasted cannot be rejected out of hand.

Patents

Newly accessible databases in the United States and Canada make corporate patent applications and granting figures readily available. Patents are better indicators of innovation as an output than is R&D. But patent data can sometimes be misleading. First, from an economic standpoint, innovation is about applying new ideas and technology to improve human life, not just about having ideas. High patent counts do not necessarily mean a high level of innovation. Second, firms that have a new technology and fear that other firms might try to steal their technology by finding superficially different technological processes that circumvent the innovator's patent are thought to engage in *patent thicketing*. This involves filing numerous patents on minor variants of the original patent, not because these are real innovations, but because they "might" head off a competitor's attempt to circumvent the original patent. Also, patent laws can be very different in different countries. For example, Japan allowed seven-year patents to be filed for minimal innovations, while most other countries only granted patents for real innovations, and those patents lasted for close to twenty years. Patent laws in different countries are now converging, so these problems will not affect very recent and future years' data. But it is difficult to use historical patent data in cross-country comparisons without controlling carefully for these factors. Third, many types of innovation, including software and some biological innovations, are not patentable in many countries. Lanjouw et al. (1998) discuss the imperfection of patent counts as measures of innovative output, and methods of dealing with at least some of the problems listed above.

Innovation Counts

Innovation counts are comprehensive lists of innovations made by various firms. They are usually constructed from large surveys. In principle, innovation counts should be the best data, for they clearly measure output, and the survey organizers can apply similar rules in constructing data for different firms, industries and countries. In practice, innovation counting is often criticized as arbitrary. The surveyors must decide what is an "innovation" and what is not. Patent counts also usually try to distinguish "important" from "unimportant" innovations, but this too is a judgment call. Finally, innovation counts are not available at the firm level in most countries.

Industry and country-level data can be constructed from firm-level data, so these variables can be used in macro-economic as well as micro-economic studies.

THE IMPORTANCE OF INNOVATION

DAVID LANDES (1969) DID NOT EXAGGERATE when he described the industrial revolution and the financial and technological advances that propelled it "The Unbound Prometheus" (London: Cambridge University Press, 1969). Indeed, the rapid technological advances of the early twentieth century inspired John Maynard Keynes (1936, p. 369) to write of a near future characterized by ubiquitous surpluses and overproduction:

> [T]he day... not far off when the Economic Problem will take the back seat where it belongs, and that the arena of the heart and head will be occupied... by our real problems — the problems of life and of human relations, of creation and behavior and religion. And on that day: We shall... rid ourselves of many of the pseudo-moral principles which have hag-ridden us for two hundred years... We shall... assess... the love of money as a possession — as distinguished from the love of money as a means to the enjoyments and realities of life — for what it is... one of those semi-criminal, semi-pathological propensities which one hands over with a shudder to the specialists in mental disease.

DeLong (1998), summarizing the empirical data on standards of living, finds that "The past six generations of modern economic growth mark the greatest break in human technological capabilities and material living standards since the evolution of language or the discovery of fire." But he is sceptical about Keynes' prediction, and similar predictions by Marxists like Lenin, that economic issues would fade to insignificance quickly. He notes that " ... 200 years of history tell us plainly that Keynes and Lenin were wrong: that material desires are never sated, and never lose importance in the relative scale of human concerns." Because of this, Easterlin (1996) calls humanity's incomplete victory over poverty a hollow one, because it has not been accompanied by any diminution of the psychological pressures for further victories. DeLong (1998), also considering this issue, writes "I would be greatly saddened to learn that my descendants 2,000 years hence will have lost their technology, and reverted to hunting and gathering — even if I were also assured that sociologists using questionnaires to measure their subjective 'happiness' would conclude that they were as happy as we."

Yet only in the last few decades have corporate executives and public policy makers throughout the world come to accept that innovation in general is something to be urged forward — that the benefits of innovation greatly outweigh the costs. This change of heart has occurred for two reasons.

First, economies that fostered innovation, perhaps by accident rather than design, have prospered relative to countries in which innovation was impeded by culture, regulations, or other stumbling blocks. Industry Canada's *Strategis* database contains the country of residence of each patent holder. Dropping Canada from the sample because Canadian patents may be over-represented, one finds that the correlation between a country's log per capita GDP and the number of patents its residents hold is +0.36, significant at the 1 percent level.

The correlation between a country's log per capita GDP and the log of the number of patents its residents hold normalized by GDP is +0.69, significant at the 0.001 percent level. Other theoretical and empirical work supporting the contention that innovative economies are prosperous is ample. See, for example, Jacobs (1969, 1984), Landes (1969), Murphy et al. (1991), Porter (1990), Romer (1986, 1994), Rosenberg and Birdzell (1986), and many more.

Second, firms that spend heavily on R&D post better financial performance than firms that do not. Hall et al. (1993) show that firms with high R&D spending have above industry-average financial performance, as illustrated by high average q ratios. They also show that apparent declines in the value of R&D spending, which they documented in earlier work, are due to more rapid economic depreciation of R&D in the computer industry. Chan et al. (1990) show that suddenly increased R&D budgets are associated with increased firm value. Pakes (1985) concludes that events significantly correlated with unexpected increases in R&D or patents cause the market to assign increased value to the firm in question. These findings are consistent with the view that American shareholders like long-term investments in R&D.

Despite the many problems associated with using patents as a measure of innovation, similar basic correlations appear there. For example, a similar pattern holds with private sector R&D spending and per capita GDP. Innovation counts are not available for enough countries to make an estimated relationship statistically meaningful.

As we shall argue below, there are many reasons to expect that innovation raises per capita GDP and that higher per capita GDP also raises the pace of innovation.

A Different Dimension of Competition

According to Schumpeter (1912, 1942), who invented the modern usage of the word, innovation is the process whereby a firm brings new technology into the economy. Schumpeter connects new technology to economic growth by highlighting a flaw in standard neoclassical micro-economic theory.

Neoclassical economic theory is based on the assumption of perfect competition between firms producing similar outputs with similar inputs. Competition is important in this context because it prevents any individual firm from raising the price of its output to more than what covers the costs of its inputs, including managers' competitively set salaries and a fair return to investors.

Innovation is a process that fundamentally violates this assumption. Firms that develop innovative and cheaper ways of producing existing goods can lower their costs, and so make extra profits from the prevailing price for their output. Firms that develop new and better products can similarly earn profits in excess of their input costs because they alone can produce the new products. In both cases, the basic idea is that innovation gives the innovative firm a degree of monopoly power. Figure 2 illustrates this concept.

Kirzner (1985) likens entrepreneurship to financial arbitrage, in that the entrepreneur sees how to spend \$X for inputs and later get \$X + \$Y for its output, just as an arbitrageur buys \$X worth of financial assets now in order to sell them later for \$X + \$Y. Both do what they do because they have better information, the innovator about the production process, and the arbitrageur about future securities prices.

Yet, the innovator's monopoly power does not harm consumers. It is based on an improved product or an improved production process that, in either case, makes consumers better off. If they were not better off buying from the innovator, they would continue buying from its competitors. If consumers prefer the innovator's new product, or its old product at a slightly lower price, the innovator can steal market share from its non-innovative competitors, yet still earn profits above its input costs.

Schumpeter argued that competition in neoclassical economics takes on a new dimension when one thinks about innovation. Firms compete to innovate as well as to cut prices, and competition to innovate may be the more important of the two, for successful innovation bestows monopoly profits upon the innovator.

FIGURE 2

ECONOMIC THEORY AND INNOVATION

Innovation can involve making new products using old technology, making old products with new technology, or making new products with new technology. Standard neoclassical economic theory assumes that all economic activity involves making old products with old technology.

	OLD GOODS AND SERVICES	NEW GOODS AND SERVICES
Old technology	1. Standard neoclassical economic theory	2. Making new products using known technology
New technology	3. Cheaper or better ways of making existing products	4. Making new products using new technology

This monopoly is not, however, the comfortable perch of the ordinary monopolist — protected from competitors by permanent barriers to entry. Yesterday's innovator is often today's unimaginative corporate bureaucracy. Just as IBM built a virtual monopoly over the mainframe computer business in the 1960s and 1970s with its innovative products, innovative personal computer makers and software designers destroyed its monopoly power in the 1980s and, in some cases, substituted their own technological monopolies. The monopoly power that comes from controlling new technology only lasts until the next piece of better technology comes along, and today's creative firm is destroyed by tomorrow's upstart.[2]

ECONOMIC SELECTION

CHARLES DARWIN (1909) ATTRIBUTES THE GERM of his ideas about natural selection to Thomas Malthus (1789). In fact, economic selection differs from natural selection in one critical way. In Darwinian natural selection, plants and animals with hereditary traits that lessen their chances of survival die out, leaving those with hereditary traits that increase their survival odds to prosper and multiply. In economic selection, firms change their traits through innovation, and the firms that innovate creatively, and in ways that consumers value most, come to dominate their markets. In contrast, firms that do not innovate, or that innovate in ways consumers do not value, are destroyed by their more creative competitors. Schumpeter (1942) calls this process of economic selection, the culling of non-innovative firms, *creative destruction*. Creative firms prosper, but non-innovative firms are destroyed. The term Schumpeterian evolution is also used to describe creative destruction. Schumpeterian evolution, like Darwinian evolution, is the survival of the fittest. But in Schumpeterian evolution, firms purposefully make themselves the fittest by investing in innovation.

Interestingly, this type of evolution was proposed for animals by Lamarck (1809), who suggested that giraffes have long necks because they stretched them by straining to reach higher leaves, and this modified neck was passed on to subsequent generations of giraffes. When the genetic basis of biological traits became clear, Lamarckian evolution was discarded, only to be resurrected by Schumpeter in the twentieth century.

We can measure the pace of creative destruction. Audretsch (1995) shows that the turnover of the list of firms in the Fortune 500 has increased rapidly over the past two decades, and that the majority of new jobs are in industries that were insignificant two decades ago. This result, and other corroborating evidence, support the view that the pace of innovation in the United States has accelerated sharply in recent decades.

The Determinants of Innovation

As Kirzner (1985) points out, a sort of Heisenberg uncertainty principle haunts any detailed description of innovation, for the act of describing entrepreneurial activity clearly makes what is described a routine, and no longer an innovation.

This paper explores what economists know about the economics of innovation. This is a huge subdiscipline of economics containing a vast literature. Numerous theoretical models of innovation are described well in Kirzner (1997), but are not the focus of this overview. Rather, this paper identifies key empirical research on different aspects of what we think causes the pace of innovation to be faster or slower. The remainder of this paper is therefore a selective survey of empirical work on the determinants of Schumpeterian innovation, guided by relevant economic theory. The survey is selective because this literature is huge. To make this study a paper, rather than a multi-volume tome, we ignore those parts of the literature that have taken wrong turns or arrived at intellectual dead ends. We make exceptions for ideas that are empirically disproved but still retain a degree of popular support.

Innovation and the Economics of Information

The value of an innovation to a firm is based on that firm having proprietary information about how to make a cheaper or better product. According to Caves (1982), information is different from ordinary economic goods in two ways.

Information Is a Quasi-public Good

A *private good* is a good that can be consumed only once. An example is a pie. If one person has eaten it, no one else can eat the same pie. In contrast, a *public good* is a good that can be used (consumed) by many people at once. An example is a national defence system. It can protect millions of people from foreign invasion simultaneously. The fact that one person is protected in no way reduces the protection of other people. Neoclassical economic theory assumes that private goods are the rule and public goods the exception (Varian, 1992).

Many goods have a mixture of private and public characteristics. For example, a school is a public good in that many students can consume the same education at once. But if the school becomes so crowded that adding another student deteriorates the quality of the education existing students are receiving, the school is taking on the characteristics of a private good. Goods like education that are primarily public goods are called *quasi-public goods*.

The sort of information that underlies innovation is also a quasi-public good. If one person devises a better way of producing widgets, the same technique can be used in every widget factory without any physical harm to its use in the innovator's factory. This is true until the increased use of the innovation starts to drive up the costs of any special input it requires — for example, skilled workers trained to operate new equipment. These quasi-public good characteristics are the first way in which Caves (1982) holds that information differs from ordinary goods.

The normal laws of supply and demand break down when applied to public and quasi-public goods. A group of individuals might pool their resources to build a missile defence system. But they could not prevent a neighbour, who claims he has no need for such a system even though he does, from enjoying the protection they are paying for. The usual solution to this "free-rider" problem is to have governments provide public goods and use their police powers to force everyone who benefits to pay (Atkinson and Stiglitz, 1980).

The information behind an innovation is protected in this way. Patent laws are a manifestation of the state's police powers designed to prevent other people from "free-riding" on an innovator's idea. Other widget makers can use the new production process developed by the innovator, but they must get his permission and pay him a licence fee.

Information Has Increasing Returns to Scale

THE MAJOR COSTS OF CREATING AN INNOVATION are often up-front costs. Consider a new pharmaceutical product. According to Gambardella (1995), about 30 percent of a pharmaceutical firm's costs relate to clinical testing, while 50 percent relate to pre-clinical research, which occurs a decade before marketing. Production and marketing costs are typically 20 percent or less. This means that, when an innovative product does hit the market, most of its costs are already sunk, and the marginal cost of producing another tablet of a new medication is typically very small. Since patent laws give the innovator a temporary monopoly over the medication, the innovator can charge a price that exceeds its cost of production. Therefore, the more tablets the innovator produces and sells, the greater its profit.

For example, consider a new drug that cost $10 million in R&D and testing costs to bring to market. Suppose each tablet costs 25¢ to make but can be sold for $1.25. The return on the $10 million up-front investment is therefore 10 percent per year if 1 million tablets are sold each subsequent year, 20 percent if 2 million tablets are sold each year, and 50 percent if 5 million tablets are sold each year. The return on the innovator's initial investment therefore rises as the scale of its production increases. Such a firm is said to have *increasing returns to scale*. These increasing returns to scale typically continue until the firm's scale of operations is very large indeed.

This situation is very different from most economic production, for unit costs are usually much higher and, beyond a certain level, tend to rise with the scale of production. For example, a non-innovative agribusiness might be able to increase its output by planting its crops more densely, but this tends to stunt plant growth unless large amounts of fertilizer and pesticides are used. The agribusiness might be able to buy or rent more land to plant on, but this also adds to the cost of each additional bushel of its crop. Since the agribusiness has no monopoly protection, it cannot sell its larger crops at prices that exceed the costs its competitors face, for it will lose its customers. Beyond a certain point, therefore, the costs of an increased crop size exceed the additional revenue the firm gets, and further expansion makes no sense. Such a firm is said to have *decreasing returns to scale* beyond its *optimal scale* of production. Neoclassical economics assumes that decreasing returns to scale usually set in at relatively low scales of production.

Dosi (1998) provides a more detailed theoretical overview of these and other unusual economic properties of information, and information-based assets like innovation. He argues that firms produce goods in ways technically different from the products and methods of other firms and that innovations are based largely on in-house technology containing elements of tacit and specific knowledge. Caves (1982) offers a highly readable and less formal overview of the same basic topic as it is relevant to the determinants of innovation.

DOES THE STRENGTH OF INTELLECTUAL PROPERTY RIGHTS DETERMINE THE PACE OF INNOVATION?

IN THE PREVIOUS SECTION, we argued that the information behind an innovation must be protected by intellectual property rights legislation such as patent laws. These laws enlist the state's police powers to prevent other people from "free-riding" on an innovator's idea. Other widget makers can use the new production process developed by the innovator, but they must get his permission and pay him a license fee. How strong should intellectual property rights be? The embarrassing answer is, we're not sure. This section is about why.

STATIC AND DYNAMIC OPTIMALITY

SCHUMPETER (1942) SHOWED THAT STATIC EFFICIENCY (looking at current conditions only) may conflict with dynamic efficiency (associated with current and future conditions). Static, or short-term, efficiency considerations led computer firms to use two digit dates to reduce data storage costs. The Y2K problem seemed far enough in the future to ignore until the 1990s. Ecologists suggest that the widespread use of antibiotics in animal feed is a similar situation, where short-term static efficiency considerations are inconsistent with long-term dynamic efficiency.

In a one-period model of an economy, the extra profits a monopoly collects, its *monopoly rent*, are associated with extra costs to consumers, and are consequently inefficient in the static setting. Griliches and Cockburn (1994) find that, when the patent on a drug expires, there are substantial welfare gains to consumers who regard branded and generic versions as perfect substitutes, though they note large amounts of scatter in their data. Thus, consumers must pay more for the patent protected firm's goods than they would if many competitive firms were producing them. The term *rent* signifies a "pure profit" from the viewpoint of static efficiency. Thus, monopoly profits are called monopoly rents. Schumpeter argued that the monopoly rents an innovator collects are not rents from a dynamic point of view. They are returns to investment in innovation when seen in a dynamic context.

While static economic theory has been developed and refined for well over a century, dynamic efficiency models are relatively new additions to the field, and are only now becoming important in applied economics. These models, which formalize Schumpeterian innovation, are referred to as the *endogenous growth theory*.

An example of such a theory is that of Romer (1986), who adds private and public information as additional inputs in firms' production functions. His study shows that a certain level of investment in information is "dynamically optimal" in each period, in that it maximizes the present discounted value of current and future consumer utility. A certain level of intellectual property rights protection is implicit in this analysis, though no meaningful determination of the optimal level is possible from purely theoretical work. Other models are Bayesian learning, due to Jovanovic (1982), and a model of research and exploration offered by Ericson and Pakes (1995). An interesting model in this area is that of Baldwin (1995), which uses Canadian census data to document that mobility and turbulence are ever more often the rule, and that long periods of stability, when the static model is valid, are likely to be ever rarer. He develops an evolutionary model of dynamic competition that links the magnitude of such turbulence to traditional measures of static competition.

Nordhaus (1969) developed the first model of optimal patent protection. Longer patent lives give a greater financial incentive to prospective innovators, but also slow the diffusion of an innovation through the economy. The optimal patent life balances these two factors. Nordhaus' theory has stood the test of time. But honest economists must admit that they have little idea about what the optimal patent life should be, whether it is the same across industries or how it should differ across industries, or whether patent lives should be the same for different innovations in the same industry. We also do not know whether current patent laws provide optimal, sub-optimal or super-optimal patent lives. Economic theoreticians, for example Scotchmer and Green (1990), Scotchmer (1996), and O'Donoghue et al. (1998), are producing interesting models for exploring these issues, but little is known about the parameter values needed to operationalize them. These issues are examined in the Canadian context in Anderson and Gallini (1998).

Patent protection also has many gaps. Many countries do not have meaningful patent laws, perhaps because they recognize that few innovations are likely to occur in their own economy. Their government's optimal strategy is, therefore, to allow state-of-the-art technology to be used everywhere. This done, ordinary neoclassical price competition occurs, and consumers have access to innovators' products at prices that fall until they just cover producers' input costs. Allegations by the United States that China is acting in this way are at the core of many trade problems between these two economies. Even in countries that vigorously protect patent rights, corporate espionage, reverse engineering, and superficial alternate designs can evade or circumvent patent protection. Consequently, innovative corporations tend to protect financially important innovations with a cloak of secrecy. Levin et al. (1987) survey 650 individuals in 130 lines of business and find that patents are rated as the least effective means of protecting process innovations, behind secrecy, superior sales and service efforts, learning and experience, and lead time. About 60 percent of the respondents reported that competitors could easily invent around a patent. Performing independent R&D was rated the most effective means of getting information about new technology developed by others.

EMPIRICAL EVIDENCE ON THE VALUE OF INTELLECTUAL PROPERTY RIGHTS

PAKES AND ERICSON (1998) FIND THAT THE LATTER TWO are at least partially consistent with the data. Cockburn and Griliches (1988) find some evidence of interaction between industry-level measures of patent effectiveness and the market's valuation of a firm's past R&D and patenting performance, as well as its current R&D efforts. Pakes and Schankerman (1986) and Pakes and Simpson (1989) take a first step toward fleshing out more details on this issue. In some countries, patent holders must pay renewal fees to maintain their patent protection. These studies estimate the private value of patent rights in the United Kingdom, France, and Germany from cohort data on the number of patents renewed at different ages, the total number of patent applications, and patent renewal costs. They find that the distribution of private value of patent rights is sharply skewed, with a heavy concentration of patent rights having very little private economic value, and has an extended positive tail. They also find a sharp change in the 1960s, after which the number of patents fell, but their quality rose. Lanjouw et al. (1998) extend this approach to estimate how the value of patent protection would vary under alternative legal rules and renewal fees and with various estimates of the international flow of returns from the patent system.

Mutti and Yeung (1996) take a different approach. They measure the effect of unfavourable dispositions of court cases dealing with intellectual property rights infringement by importers on the intellectual property owner. They find that such decisions are associated with five to seven percent drops in profit-to-sales ratios. Unfortunately, they are only able to study 59 such cases, so further work in this area is needed. Mutti and Yeung (1997) further find that these negative dispositions in section 337 cases appear to stimulate subsequent R&D intensity in the plaintiff's industry. In contrast, positive dispositions are, at best, associated with no reduction in R&D spending. Hence, they argue that intellectual property rights might currently be too strong, rather than too weak.

THE IMPORTANCE OF BEING FIRST

MERTON (1957, 1968, 1969, 1973, 1988) DOCUMENTS THE FACT that intellectual property rights are, and have been for three centuries at least, awarded to the first person to publicize a finding. This is true in both commercial and academic research. Only being first matters: quality, effort, or other factors do not enter. There are no awards for being second or third. This winner-takes-all reward structure (Frank and Cook, 1992) resembles the practice of offering a prize to the first firm to successfully complete a well-defined project (Wright, 1983).

"First at what?" also matters. The first conceptual innovator is not necessarily the winner that takes everything. Economic victory often goes to the first to realize and exploit an innovation's economic importance. "White Castle" was the first to serve fast-food hamburgers, but the real winner was McDonald's, the first to realize the true economic importance of standardized, quick, and spotlessly clean restaurants. Xerox was the first mover in PC systems, but Xerox managers failed to realize the economic importance of what they had. The economic victory went to Microsoft, which did. Glazer (1985) documents this, and suggests that there may often be a "second mover" advantage. Mitchell et al. (1994) suggest that second movers can learn from first movers' implementation mistakes, and so can enter the market more cheaply. First movers cultivate the fields, but die of malaria. Second movers find the ground cultivated, and bring mosquito nets.

Even in academic research, the first mover is often not the big winner. The mathematics of option pricing was fully developed by the French economist Louis Bachelier in 1900. It remained an obscure scholarly topic until Black and Scholes (1973) independently reinvented it some seventy years later, and realized its economic importance. Uranus was mapped on star charts repeatedly before it was "discovered" by William Herschel in 1781. Previous star gazers had failed to realize that the occasional, and irreproducible, reports of "stars" in various parts of the sky added up to the orbit of a seventh planet. Even if Canadians win few Nobel prizes, they could still be the "winner that takes all" if they, like Bill Gates, were the first to realize (and act on) the economic implications of new knowledge.

Stephan (1996) notes two consequences of this winner-takes-all reward system in both industrial and academic research. One is the rush to publish or patent. Another is the energy firms and academics sometimes devote to establishing priority over rival claims. Merton (1969) describes the extreme measures Newton took to establish that he, not Leibniz, invented calculus. Why is research structured as winner-takes-all contests? First, monitoring research effort is very difficult (Dasgupta and David, 1987; Dasgupta, 1989). Lazear and Rosen (1981) note that this is an incentive-compatible compensation scheme where monitoring is difficult. Second, the runner-up really does make no social contribution *ex post*. As Stephan notes, "There is no value added when the same discovery is made a second, third, or fourth time (Dasgupta and Maskin, 1987)."

Because this winner-takes-all tournament causes researchers to bear substantial risk, compensation in science often has two parts: a base pay that is unrelated to success in winner-takes-all contests, and another linked to the priority gained in important research undertakings. This also explains the great effort universities exert to evaluate publications and count citations, as shown in Diamond (1986), and Tuckman and Leahey (1975).

The economic sense of this winner-takes-all system is evident. Shirking makes little sense most of the time. Researchers share quickly to establish priority. This allows for peer evaluation to discourage fraud and consensus-based conclusions (Dasgupta and David, 1987; Ziman, 1994). It also allows researchers to establish reputations, and this loosens up research funding for them. Arrow (1987) describes how a winner-takes-all system offers non-market-based incentives for producing public good "knowledge." Dasgupta and David (1987) concur, noting that "Priority creates a privately-owned asset, a form of intellectual property, from the very act of relinquishing exclusive possession of the new knowledge." Also, as Stephan (1996) notes, "A reward system based on reputation is a mechanism for capturing the externalities associated with discovery. The more a scientist's work is used, the larger is the scientist's reputation and the larger are the financial rewards. It is not only that the reward structure of science provides a means for capturing externalities. The public nature of knowledge encourages use by others, which in turn enhances the reputation of the researcher" (Stephan and Levin, 1996).

However, entrenched insiders having too much control can also explain such empirical observations. There are numerous instances of entrenched senior researchers blocking innovative youngsters who threaten their reputation. The phenomenon is called *Planck's Principle*, after Max Planck (1949), who wrote in his autobiography that a new scientific truth does not triumph because its supporters enlighten its opponents, but because its opponents eventually die, and a new generation grows up that is familiar with it. Examples include the deciphering of Mayan hieroglyphs, the discovery of continental drift (Stewart, 1986; Messeri, 1988), Darwin's ideas on evolution (Hull et al. 1978; Hull, 1988), and many other cases. Statistical evidence from studies of scientists' age and their willingness to accept new theories indicates that this effect exists, but may not be very strong. The business analogue of this is the erection of entry barriers by established firms and the discouragement of radical innovation within these firms.

In contrast, it is statistically very clear that winning research tournaments appears to increase one's odds of winning again. In academia, this is reflected in the highly skewed distribution of publications, such as that found by Lotka (1926) in nineteenth century physics journals. About 6 percent of publishing scientists accounted for 50 percent of published papers. "Lotka's Law" has subsequently been shown to describe many other fields. It is consistent with either an entrenched insider effect or a highly skewed distribution of priority.

Do Firm Size and Market Structure Determine the Pace of Innovation?

Caves (1982) argues that these two unique features of information, its quasi-public good properties and its increasing returns to scale, have important economic consequences. Because information and the innovations that result from it have increasing returns to scale until their scale of application is very large, innovators would like to apply their innovations on a very large scale very quickly. Because of its quasi-public good properties, retaining ownership of a knowledge-based asset like innovation is critical.

One way to retain such ownership is through patent licensing contracts, where the innovator allows its competitors to use his innovation in return for most of the profits they make from it. Caves (1982) argues that gaps in patent laws often make this impractical, for the innovator can easily lose ownership of his innovation because of reverse engineering, superficially different technology, and the like. In such a situation, the innovator has little choice but to keep the innovation secret and to run very large-scale production operations. There are two ways to do this.

One is that the innovator's firm be large to start with. Morck and Yeung (1991) find that a firm's corporate R&D spending is positively related to its average q ratio, the ratio of the actual value of its securities in financial markets to the estimated value of its productive assets.[3] More importantly, they find that in larger firms (with size measured by the number of countries in which the firm operates), the positive effect of increased R&D on q ratios is magnified significantly. The same R&D spending is more valuable to a bigger firm. Mitchell et al. (1999) find that geographic expansion precedes increased spending on R&D, while increased R&D spending does not precede expansion. Morck and Yeung (1999) find that other measures of firm size, like total sales and the number of industries in which the firm operates, similarly magnify the extra value each dollar of R&D adds to the firm's share price.

Another way in which a firm can capture the increasing returns to scale associated with its innovation is to grow very, very quickly. In general, the best way for a firm to become very large very fast is through corporate mergers or takeovers. Morck and Yeung (1999) call such mergers and takeovers *synergistic*, and the added value of applying an innovation to the operations of the other firm the *synergy* produced by the merger. Morck and Yeung (1992) find that the acquirer firm's stock price rises more upon taking over a foreign firm if its R&D spending has been higher. Morck and Yeung (1999) find that high R&D firms are abnormally likely to be involved in friendly mergers.

Schumpeter (1912) argues that small firms are best at innovating. Schumpeter (1942) reverses this and argues that all monopoly is not bad, and that allowing monopolies based on innovation is in the public interest. He further argues that large monopolistic firms are the best innovators because they can use their monopoly profits to fund research into innovations. Competitive firms do not have the cash cushion of monopoly profits and so are unable to finance innovations. Since innovative activity is associated with, and to some extent at least, causes a country's living standards to rise, monopolies that sustain a higher pace of innovation are therefore in the public interest.

Scherer (1992) surveys the empirical literature and concludes that Schumpeter (1942), though essentially proved correct about creative destruction, overstates the advantages of large, monopolistic corporations as engines of technological change. He comments that it is far from clear that countries "should reallocate innovative activity away from venture firms to the well-established giants lauded in Schumpeter's (1942) book." Geroski (1994) supports this view. He uses innovation counts for U.K. firms from 1945 to 1983 to show that monopolistic industries are less innovative.

Geroski (1994) also finds that innovation-producing firms perform better than non-innovators, especially during economic downturns, but argues that this difference is due to firm characteristics that give rise to innovation, not to incentives and opportunities. Firms must organize themselves to respond effectively to opportunities and incentives with valuable innovations. If so, this qualifies the view that established firms should be allowed to fail so that new firms can replace them. Further research is needed on which firm characteristics or organizational structures matter most.

But Scherer (1992) goes on to say that Schumpeter's view is not completely wrong, and that big, monopolistic firms may indeed be best positioned to undertake certain types of innovation. Scherer suggests that "it may be no accident that the United States retains a strong lead in microprocessor semiconductor chips, where bold product design advances can capture the market", since that country has the world's most developed venture finance system for funding small innovative startups.

If Schumpeter (1942) is correct, anti-monopoly laws may have perverse effects. In the United States, the Federal Trade Commission (FTC) uses the Herfindahl-Hirschman Index

$$HHI = \sum_{\text{All Firms in the Industry}} \left[\frac{\text{Firm Sales}}{\sum_{\text{All Firms in the Industry}} \text{Sales}} \right]^2$$

as an indicator of whether or not an industry is subject to monopoly power. If each of the ten firms in an industry had 10 percent of the industry sales, the *HHI* would equal 10×10^2 or 1,000. If one firm had 91 percent of the market and the other 9 each held 1 percent, the *HHI* would be $91^2 + 9 \times 1$ or 8,290. An HHI under 1,000 is considered an indicator of healthy competition. An *HHI* increase of 1,000 or more is likely to trigger an investigation, and an *HHI* above 1,800 is considered *prima facie* evidence of a monopoly.

Although the merger and acquisition (M&A) provisions of current U.S. antitrust law make explicit reference to market share calculations such as those described above, in the absence of M&A activity, the Federal Trade Commission and the Department of Justice consider other factors as well. Moreover, even if M&A activity triggered the investigation, the defendant can argue that the monopoly was "thrust upon him" by virtue of an innovation. However, the burden of proof is then on the defendant.

The FTC also considers barriers to entry and competitors' attitudes toward the dominant firm before filing antitrust charges. If barriers to entry are low and competitors are not complaining, the FTC stays its hand. Although the U.S. government prosecutes such cases, they generally result from complaints filed by competitors. Ellert (1975, 1976) examines mergers between 1950 and 1972, and finds that residual performance measures, considered an indicator of productivity, were above average for defendants during the four years prior to the complaint and fell to the average level during the year of the complaint. Ellert points out that non-innovative competitors have strong incentives to file antitrust complaints against innovators because the government bears the cost of prosecution while the defendants must pay their own legal costs. Ellert suggests that antitrust complaints are often a form of harassment exerted against strong innovative firms by weak stagnant firms.

Canada's anti-combines legislation is more focused on barriers to entry. As long as proprietary technology and other innovations are not considered barriers to entry, Canada's laws would appear to be better. Unfortunately, innovative Canadian firms must expand quickly into the U.S. market to achieve the economies of scale that will optimize their returns, and thus become subject to U.S. antitrust legislation.

Eckbo (1992) finds that Canada's adoption of its current anti-combines legislation at the end of the 1980s did not slow down the pace of M&A activity in that country. The potential negative spin on this finding is that the new law is ineffective. Its potential positive spin is that most M&A activity was synergistic and not aimed at creating monopoly power based on sheer size, so M&A activity continued apace.

Certainly, entry is important. Acs et al. (1997), like Scherer (1992), argue that new firms are required for radical innovation, and that large established firms tend to focus mainly on incremental improvements in existing products and processes. They cite intellectual property rights as the key reason for this.

First, an innovator has clear control over innovations in his own firm. Innovations in a large firm are usually the property of the firm, with the innovator often getting only a raise or a promotion. People with radically new ideas therefore often prefer to start their own firm.

Second, the office politics of large firms often stifle radical innovations. The senior managers of an established firm are often the past innovators who caused that firm to grow. As long as the firm remains dependent on the innovations they produced, they are the best people to manage its operations. If a radical new innovation rendered their contribution obsolete, they may no longer be the best people to run the firm. Betz (1993) argues that the mainframe computer engineers at IBM took this position when personal computers began to take off in the early 1980s. Instead of embracing this radically new technology, IBM's top people decided to concentrate on incremental innovation aimed at improving their mainframe products. Thus, people with radically new ideas may find themselves rejected by large established companies.

Still, market entry can be a daunting experience for a small firm; and one that often ends in failure. Large firms usually have more resources and experience in market entry. Acs et al. (1997) argue that "intermediated" market entry can sometimes be a solution to this imbalance. Small radical innovators can enter a market via a large firm by selling either their output or their technology to the bigger firm. The advantage of such an arrangement for the small innovator is that it eliminates the costs of market entry. The disadvantage is that the big firm takes a cut. Which route is best depends on the relative bargaining power of the two firms and on the nature of the market.[4]

Audretsch (1995) analyses a U.S. Small Business Administration survey of over 8,000 innovations introduced in 1982, each classified by industry, significance and firm size. He uses the small-firm share of innovation in each industry as an indicator of established firms' underlying attitudes to innovation. He argues that these attitudes affect how open firms are to new ideas and the chances of success of new firms. He calls industries in which most innovations are done in large firms "routinized". In these industries, corporate decision makers generally agree about the expected present value of potential innovations, so innovations are likely to be funded and developed by existing firms. He calls industries with relatively high small-firm innovation shares "entrepreneurial", and argues that innovators' and managers' appraisals of the value of prospective innovations diverge in these industries. Audretsch finds that observed patterns of entry, exit, and evolution in manufacturing firms are explained by the classification of firms into these two different "technological regimes".

Gambardella (1995) notes that small biotechnology firms tend to come up with radical new discoveries, but are often incapable of doing the clinical trials needed to get regulatory approval. They also lack marketing and distribution expertise. He concludes that the "result has been a new division of labour, with smaller firms specializing in early research and larger firms conducting clinical development and distribution. Although the larger firms still do extensive basic research themselves, they have entered into a growing number of alliances and joint agreements."

Overall, market structure does appear to affect both the pace of innovation and the types of innovations generated, with large firms producing incremental innovations and smaller firms producing more radical innovations. But market structure can also be an endogenous outcome, affected by (rather than affecting) the pace and phase of innovation. At the early stage of an innovation's evolution, there are often many sellers. As the innovation is refined, a shake-out occurs. For example, in the 1990s, the PC industry went from many to only a few suppliers. So did the software industry.

DOES THE GEOGRAPHIC DISTRIBUTION OF FIRMS DETERMINE THE PACE OF INNOVATION?

IN 1890, ALFRED MARSHALL WROTE that the concentration of industry in cities allows knowledge to spread from firm to firm rapidly, and that this should fuel economic growth. Arrow (1962a,b) formalizes this idea, and Romer (1986) offers a prominent restatement. This transfer of knowledge from firm to firm is called *knowledge spillover*, and is an example of what economists call a positive externality.

Griliches (1979) surveys the empirical literature on knowledge spillovers. Loury (1979), Dasgupta and Stiglitz (1980), and Romer (1986) develop influential models of this process. Romer (1986) and Lucas (1988) argue that such knowledge spillover externalities are the motive power behind economic growth. Griliches and Hjorth-Andersen (1992) argue that spillovers account for up to half the growth in output-per-employee and about 75 percent of the measured total factor productivity (TFP) growth in the United States.

Three different variants of knowledge spillovers have been proposed. First, Marshall (1890), Arrow (1962a,b) and Romer (1986) take the view that spillovers occur more readily between firms in the same industry, and that a concentration of industrial activity in a line of business in one city should therefore accelerate its economic growth. The idea is that existing large-scale industrial activity means innovations can immediately be applied on a larger scale and therefore generate more profit. If competing firms steal an innovator's idea, the innovator's return on its innovation is lowered. Consequently, monopolistic production should facilitate a faster pace of innovation. This resonates with Schumpeter (1942) — local monopolies are better for economic growth than competition because local monopolies have no competitors to steal their ideas and therefore invest more in innovation. Thus, the fact that their employees gossip to each other makes innovation less profitable than it might be for Silicon Valley chip manufacturers.

Porter (1990), in a second and highly influential version of the idea of knowledge spillovers, agrees that geographically concentrated industries spur growth, but would have strong competition between many local firms rather than a local monopoly. He argues that intense competition makes innovation essential to corporate survival and that this overwhelms the problem of innovations falling into competitors' hands. Thus, the fact that their employees gossip to each other makes it possible for Silicon Valley chip manufacturers to innovate faster by building on each other's discoveries.

A third version of the spillover theory is that of Jacobs (1969). She argues that the most important spillovers occur across industries, not between firms in a single industry. Rosenberg (1963) discusses how the use of machine tools spread from industry to industry, and Scherer (1982) finds that 70 percent of inventions in a given industry are applied in other industries.

If Jacobs (1969) correctly describes typical knowledge spillovers, having a variety of industries in a city should lead to higher growth than having a local economy concentrated in a single industry. In contrast, the version of knowledge spillovers proposed by Marshall (1890), Arrow (1962a,b) and Romer (1986), and that proposed by Porter (1990) both predict a higher growth rate for an economy that is focused on one industry. Marshall (1890), Arrow (1962a,b) and Romer (1986) further predict that cities with one, or at most a few, large firms in an industry should grow faster than cities with many competing firms in their key industry. Porter (1990) predicts the opposite.

Glaeser et al. (1992) test these predictions directly. They find that the U.S. urban areas that grew the fastest from 1956 to 1987 were those with a wide variety of industries. This suggests that the spillovers that contribute most to growth are cross-industry spillovers. High profile one-industry areas like Silicon Valley appear to be exceptions rather than typical as centres of economic growth. They conclude that Jacobs' version of knowledge spillovers best explains the relative growth rates of U.S. cities. Geroski (1994) examines the effects of innovation counts (for U.K. industries, from 1945 to 1983) and finds that TFP growth is positively related to innovation counts, and productivity growth is positively related to entry by domestic but not foreign firms. This is consistent with Porter (1990), but does not contradict Jacobs (1969). Overall, the empirical evidence to date is highly consistent with the version of endogenous growth theory of Jacobs (1969), somewhat supportive of that of Porter (1990), and inconsistent with the version of endogenous growth theory advanced by Marshall (1890), Arrow (1962a,b) and Romer (1986).

Although the view of Jacobs (1969) is gaining ground rapidly, the academic debate to explain geographical clustering remains open. The view of Marshall (1890), that firms locate where key inputs (and infrastructure) exist, is closely related to that of Jacobs. Bairoch (1988) reports that business located near energy sources in industrializing England. The modern analogue is fashion designers locating in New York because the skilled workers they need are found there. And the skilled workers are in New York because they can easily move from unsuccessful to successful firms. Lichtenberg (1995), Henderson (1988), Arthur (1989) and Rotemberg and Saloner (1990) develop other static localization theories along similar lines.

Finally, Henderson (1986) finds that output per worker is higher in firms that have competitors nearby. This is consistent with the view that employees who reside near clusters are more willing to invest in human capital, the value of which is dependent on the use of a particular technology or other innovation, which is again consistent with a labour market origin of clusters.

Our current knowledge of technology clusters thus points to three general features. First, geographical clusters reduce search costs in general. Second, geographical clusters specifically reduce the search costs of employers for workers and of workers for jobs. Third, the reduced risk of being forced to find unrelated work makes employees more willing to invest in technology-specific human capital, and this increases their productivity.

This geographic concentration continues until the marginal benefit of further concentration equals the marginal cost of increased crowding. If crowding were a binding constraint, growth in a city's largest industries should raise wages, rents and other costs (especially those of fixed factors like land) and so prevent other industries from growing. Glaeser et al. (1992) find that a city's smaller industries grow when its larger ones grow, and question the view that crowding has limited growth in the typical U.S. city during the period they study, 1956 to 1987.

Nonetheless, recent developments suggest that crowding may be becoming a more serious issue. In a *New York Times* article, Markoff (1999) reports that "Internet companies — and the economic growth they reap — are expanding rapidly in seven regions outside of the Valley: Seattle, Los Angeles, Austin, Boston, New York, the District of Columbia, and San Francisco's 'Multimedia Gulch'." The article describes a survey conducted for Joint Venture by A.T. Kearney, a business consulting firm, that found more than 85 percent of the executives surveyed reporting access to talent as a factor in determining the site of their Internet companies. Kearney estimates the skilled labour shortage in Silicon Valley at up to 160,000 workers, or almost 33 percent of the regional labour demand. Although Silicon Valley wages are far above the national average, astronomical housing costs and quality of life issues related to congestion are perpetuating the current skilled labour shortage.

Shaver and Flyer (2000) present evidence that the strongest and most innovative firms in clusters are the most likely to move out. They argue that adverse selection problems are responsible. Employment with the best firm in the industry is arguably the safest career, so location in a cluster is less important to its employees. Indeed, locating in a cluster exposes the firm to information leakage problems and unwanted employee turnover. Consequently, the weakest firms in a cluster are the ones for which the cluster is the most beneficial, and the strongest firms in a cluster are the most likely to move at least some of their most important operations elsewhere.

Can governments (or wealthy individuals) create new high-tech clusters by establishing a critical number of embryonic high-tech firms in a new location?

Many governments are trying. Numerous places now bill themselves as "Silicon Valley North", "Silicon Valley East", "Silicon Glen", "Silicon Tal", etc. Universities in Hong Kong, Texas, and the Middle East have tried to attract top tier researchers to create nuclei for new clusters. The results have been mixed at best. Certainly, some fading academic stars have enjoyed a deservedly comfortable semi-retirement. The construction of new research parks has greatly enriched local landowners and developers. And entrepreneurs, often using political influence as much as scientific knowledge, have used subsidies to establish some high-tech companies in those places.

Although local civic promoters adamantly defend such programs, and vigorously assert their success, thorough cost-benefit analyses of these programs are generally not possible. This is because the data necessary to estimate what private and social returns were generated is rarely made public. This lack of transparency itself suggests that real rates of return to taxpayers are embarrassingly low. Moreover, the opportunity cost of such programs is an important consideration generally ignored by their promoters.

As with market structure, the geographical distribution of an industry may be endogenous: Important innovations may attract clusters of high-tech firms, rather than the reverse. If so, governments' best bet for stimulating new clusters is to provide good infrastructure and to keep taxes low so innovators can keep the returns from their innovations. Since a healthy, well-educated population is a critical input for many innovative firms, and firms locate close to critical inputs, public spending on all levels of education and public health is perhaps justified.

But once the clusters are formed in particular places, can new ones be formed elsewhere? Jacobs (1969) emphasizes that new clusters do form, and that there are consistent patterns of how this happens. We have argued above that the benefits of locating in a cluster include the spillover of ideas and the existence of a pool of skilled labour. In addition to the obvious costs associated with crowding, the costs of locating in a cluster also include the risk that your ideas may be leaked or that your employees may leave. As Shaver and Flyer (2000) show, firms that know their ideas are better than those of other firms locate far from their competitors and in places with high quality labour. Thus, strong companies, such as Microsoft, deliberately locate important facilities far from existing clusters. In so doing, they establish new clusters in new places, like Seattle.

Finally, the Internet may alter the importance of clusters by making geographical proximity less important. The underlying issue is people working and talking with each other, not corporate addresses. Information flows and competition, not clusters *per se*, are what counts. Software programmers in India now routinely take in work from U.S. firms, and the Internet makes their physical presence in the United States unnecessary. But geography is more uncompromising in industries like pharmaceuticals, where expensive lab equipment requires a physical location.

Does Corporate Decision-Making Determine the Pace of Innovation?

People are making decisions continually at all levels in a corporation. Business schools teach courses on financial decision-making, or capital budgeting, that provide executives with tools like net present value (NPV), internal rate of return (IRR), and economic value added (EVA) analyses. Higher levels of management usually use these techniques to assist in major decisions. To help coordinate the thousands of minor decisions managers and employees make at all levels, economists recommend incentive schemes of various sorts. In this section, we first discuss textbook capital budgeting analysis, and then turn to incentive issues.

Capital Budgeting Techniques

Standard neoclassical investment models compare the initial set-up cost to the present value of future net cash flows a project is expected to produce. A straight comparison of dollar values is called an NPV analysis. Estimating the discount rate that would equate costs with the present value of expected net benefits is called IRR analysis. Annualizing initial capital costs and then doing the same comparisons is called EVA analysis.[5]

Brennan and Schwartz (1985) point out that many corporate investments are like stock options, in that there is a timing decision about "when to invest" as well as an "invest or don't invest" decision. Pindyck (1991) argues that the ability to delay irreversible investment expenditures "can profoundly affect the decision to invest. It also undermines the theoretical foundation of standard neoclassical investment models. Irreversibility may have important implications for the understanding of aggregate investment behaviour. It makes investment especially sensitive to various forms of risk, such as uncertainty over future product prices and operating costs that determine cash flows, uncertainty over future interest rates, and uncertainty over the cost and timing of the investment itself. Consequently, irreversibility may have implications for macro-economic policy." Pindyck reviews some basic models of irreversible investment to illustrate the option-like characteristics of investment opportunities. The models show how the resulting investment rules depend on various parameters from the market environment. Morck et al. (1989) show how a corporate capital expenditure decision can be analyzed using the mathematics of option pricing.

Investment in R&D often has option-like characteristics. Major auto makers may buy into a fuel cell company, not because they feel fuel cells are highly likely to triumph over alternative energy storage devices, but because they want a piece of the action if fuel cells do triumph. The auto makers are spending money to keep their "options" open in the event of a major shift in technology. Brennan and Schwartz (1985), Morck et al. (1989) and Pindyck (1991) show that investing in such options can often add to share value, even though standard simplified capital budgeting models do not come to this conclusion.

Viewing corporate investments as options is very unnatural for many CEOs and boards of directors, and has only come into reasonably widespread use among large U.S. firms in certain industries during the 1990s. This approach to capital expenditure decisions is virtually unknown in Canadian boardrooms. This is a potential problem, because option-based evaluation techniques tend to encourage higher risk strategies than do traditional methods such as NPV and IRR analysis. The continued use of old-fashioned capital budgeting tools may cause firms to take too few risks.

Evidence that typical managerial decision-making is inimical to investment in innovation comes from Cockburn and Henderson (1996), who find that pharmaceutical firms with published scientists as vice-presidents of research are more successful if those vice-presidents are corporate managers. The advantage of having a scientist, rather than an MBA, in charge of research is a clearer communication with researchers, while the cost is presumed to be that a scientist may not understand capital budgeting or other management techniques. If standard capital budgeting tools work poorly for assessing R&D, the benefit unsurprisingly outweighs the cost.

INCENTIVES

ADAM SMITH (1776) PROPOSED THAT PEOPLE ACT to advance their enlightened self-interest. Although ethicists and clerics have regularly denounced this view of human nature, actual observation of human behaviour (even that of ethicists and clerics) generally supports it. Thus, if managers wish to foster innovation, they must make innovation compatible with the interests of their employees. Corporate incentive structures generally have three components. First, employees must have the freedom and support necessary to try new approaches. Second, successful innovators must have property rights over at least part of the profits the innovation generates. Third, firms must provide incentives that encourage employees to share information.

Successful innovative companies like 3M, GE, and Citibank have entrepreneurial incentive structures that give employees such freedom, and a significant share of the results (good or bad). Cockburn and Henderson (1996), using data on pharmaceutical firms, find that the success of corporate innovation strategies hinges on how in-house scientists are compensated. Successful pharmaceutical firms use incentives to foster "directed research", rather than random shots in the dark. These incentives include financial rewards for potentially valuable new products and for better ways to direct research. The latter is often what universities would call "basic research".

Morck et al. (2000a) argue that, in Canada and other countries where established wealthy families tend to control dozens or even hundreds of interlocking corporations, another impediment to innovation arises for two reasons. First, control over a large number of firms gives these families immense political influence. Second, wealthy families have a vested interest in maintaining the economic *status quo*, and innovation often regains its original negative connotations for them. Thus, wealthy families have both the freedom to deter innovation and a financial stake in doing so. In contrast, wealthy Americans generally own only one company because intercorporate dividend taxes prevent the formation of large corporate groups. Morck et al. (2000a) call the economic dominance of wealthy old families with vested interests in preserving the *status quo* the "Canadian disease". They argue that many traditional Canadian policies have the perhaps unintended effect of protecting the inherited wealth and influence of people who might rationally want to retard innovation. These include Canada's high income taxes (which deter the formation of rival concentrations of wealth), low estate taxes (which preserve existing wealth concentrations), and a tradition of protectionism (which preserves established firms), among other things.

Does National Culture Determine the Pace of Innovation?

It is possible that some cultures are more supportive of innovation than others, and that this may affect their economic growth. La Porta et al. (1997a) find that countries where hierarchical revealed religions, like Catholicism and Islam, are dominant show poorer economic performance. Chandler (1977, 1990) argues that the U.S. economy became more purposeful between 1870 and 1910, and that this greatly enhanced the success rate of innovations.

Weber (1922) compares a traditionalist culture, where one's business partners and employees are restricted to family and friends, to a rational culture, where these restrictions have been overcome. Beninger (1986) argues that this change is due to innovations in control technology that allow principals to better monitor what their partners and employees are doing. This distributed control results from the economies of scale in information-processing innovations. Beninger's main point is that the limits of control mechanisms were the binding constraint on the speed and scale of production in the mechanical era. Control innovations were therefore critical in increasing productivity. North and Thomas (1973) emphasize innovations in control — like laws governing contracts, commercial transactions, and credit. Beninger (1986) emphasizes that control innovations include technological advances like the telegraph and telephone, railroads and mail, as well as financial innovations like banking, securities markets, import/export jobbers, and the like.

Berger and Udell (1995) show how relationships matter to small businesses with no track record in their industry or in financial affairs. These are the hallmarks of Weber's "traditionalist" cultures. Today's control technology appears unable to deal with small startups by unknown entrepreneurs in many cases.

Rosenberg (1994) argues that technology is path-dependent, and that this can lock-in "traditional ideas" that stunt economic growth.

At the risk of making overarching statements, some important implications follow. The drive to innovate is based on dissatisfaction stemming from constraints and on the belief that one can overcome these constraints. Some religions can hurt innovation because they deny people the freedom to make changes and because they teach that change is not ordained (God will provide and the Church asks us to obey and not to crave for changes in this life). Control technologies arose from the belief that we are on our own, and can make changes to overcome constraints. The importance of culture thus centers on how it affects people's attitudes toward constraints.

Controlled experiments comparing cultures are difficult to perform, but not totally impossible. Vatican II was an attempt to make the Roman Catholic Church less hierarchical and, in so doing, to change the culture of Catholic countries. It is perhaps too early to draw conclusions, but events like the Quiet Revolution in Quebec suggest success.

Can governments engineer national cultures that promote innovation? Overcoming constraints and defying established authority are part of American cultural mythology. Perhaps the global spread of American culture will also spread this mythological ideal of enterprise. Ironically, if culture affects innovation as hypothesized above, governments interested in fostering innovation should subsidize American culture, rather than decry and impede it.

Does the Financial System Determine the Pace of Innovation?

Arrow (1964) shows how financial markets can encourage risky undertakings by allowing that risk be spread across many investors. Grossman and Stiglitz (1980) show how stock prices change in response to the diffusion of information about companies' investment opportunities, thereby directing capital where it is most useful. Bernanke and Gertler (1989) show how a stable financial system matters for economic growth. Morck et al. (2000b) show how micro-level allocation of capital, toward firms that have growth opportunities and away from those that do not, is affected by the level of development of economic and political institutions in a country.

Although financial development probably fosters growth and innovation, the reverse is also undoubtedly true. Technological improvements matter in lowering financial transaction costs (Merton, 1957, 1968, 1969, 1973, 1988). Furthermore, economic growth changes savers' and investors' risk preferences and willingness to pay transaction costs (Greenwood and Jovanovic, 1990).

Thus, Levine (1997) writes "A growing body of empirical analyses, including firm-level studies, industry-level studies, individual country studies, and broad cross-country comparisons, demonstrates a strong positive link between the functioning of the financial system and long-run economic growth. Theory and evidence make it difficult to conclude that the financial system merely, and automatically, responds to industrialization and economic activity, or that financial development is an inconsequential addendum to the process of economic growth." A recent Canadian survey article by Baldwin (1997) gives no reason to doubt that this applies equally to Canada.

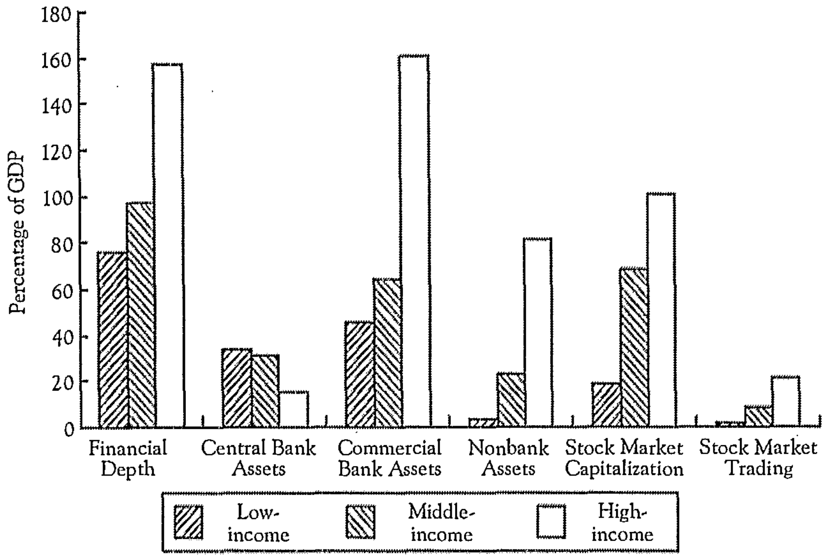
Economic growth generates the capital needed to set up financial intermediaries, while the growth of financial intermediaries accelerates overall growth by enhancing the allocation of capital. In this way, financial and economic development are jointly determined (see Greenwood and Jovanovic, 1990). Goldsmith (1969) uses the value of financial intermediary assets normalized by GNP as a measure of financial development. Based on data for 35 countries from 1860 to 1963, he finds a rough parallel growth in economic and financial development over periods of several decades, and documents limited evidence that bursts of economic growth accompany bursts of financial development. King and Levine (1993a,b,c) study 80 countries over the period 1960-89, and carefully control for several factors that might also affect long-run growth. Morck et al. (2000b) and Wurgler (2000) show that better functioning stock markets are associated with more productive capital investment across countries. Von Tunzelmann (1995) argues that numerous exogenous factors affect this co-determined evolution, and that this path-dependence explains differences in nations' economic institutions.

Of course, it is possible to invest in near valueless innovation. Dosi (1998) argues that science allows an indifferent approach to research, while business exerts powerful influence on the direction of technological search.

The cash flow from past innovations can be used by firms to finance further innovation (Schumpeter, 1942). In the absence of mechanisms for financing R&D by newcomers, this means a country's innovations may be mostly complements to existing innovations, rather than radically new products. Baumol (1993) proposes a sort of entrenchment effect for past successful innovators. Internal corporate politics sometimes lead to an inertia effect — they are slow to change.

FIGURE 3

MEASURES OF FINANCIAL DEVELOPMENT IN LOW-, MIDDLE-, AND HIGH-INCOME COUNTRIES



Source: Levine (1997).

Notes: The data are for 12 low-income economies (Bangladesh, Egypt, Ghana, Guyana, India, Indonesia, Kenya, Nigeria, Pakistan, Zaire, Zambia and Zimbabwe), 22 middle-income economies (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, El Salvador, Greece, Guatemala, Jamaica, the Republic of Korea, Malaysia, Mexico, Paraguay, The Philippines, Taiwan, Thailand, Tunisia, Turkey, Uruguay, and Venezuela), and 14 high-income economies (Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, The Netherlands, Singapore, Spain, Sweden, the United Kingdom, and the United States) data permitting. In 1990, low-income economies had an average GDP per capita of $490; middle-income economies, $2,740; and high-income economies, $20,457.

Nonbank financial institutions include insurance companies, pension funds, mutual funds, brokerage houses, and investment banks.

Financial depth is measured by currency held outside financial institutions plus demand deposits and interest-bearing liabilities of banks and nonbank financial intermediaries.

For stock market trading as a percentage of GDP, Taiwan is omitted because its trading/GDP ratio in 1990 was almost ten times larger than the next highest trading/GDP ratio (Singapore). With Taiwan included, the middle-income stock trading ratio reaches 37.3 percent.

Olley and Pakes (1996) examine technological change and deregulation in the telecommunications equipment industry. They find that productivity increases were mainly due to the reallocation of capital to more productive establishments. This suggests that the allocation of capital within each industry is economically important. Schumpeter (1942) argues that this is the case, and he stresses the importance of efficient and flexible financial markets and institutions. King and Levine (1993a) find a strong, statistically significant relationship between a country's economic performance and measures of the level of its financial sector development, and conclude that Schumpeter was right. They use four measures of financial development, and find statistically and economically significant relationships between a country's financial development and its economic performance. This is illustrated in Figure 3.

The subsector of the finance industry that is most important for financing radical innovation in the United States is the venture capital business. Kortum and Lerner (1998a) and Gompers and Lerner (1999) show that venture capital funds are immensely important in the United States, and that funding of innovations by established U.S. corporations is much less successful and much less economically important.

Venture capital funds are pools of money, analogous in some ways to mutual funds, that invest in innovations. Typically, venture capital funds focus on a particular area of innovation, such as a branch of biotechnology, and hire in-house experts (usually with PhDs in the field) to evaluate investment proposals. Experts are needed because the viability of such innovations is often impossible for laymen to gauge. The experts must be in-house staff so the venture capital fund can guarantee confidentiality to prospective innovators.

Venture capital funds are either unknown or rare curiosities outside the United States. MacIntosh (1994) studies the reasons for the absence of a dynamic venture capital business in Canada. He points out that labour unions generally have a vested interest in stability, yet Canadian tax law subsidizes venture capital funds only if they are run by a labour union. He also argues that Canada's 20 percent limit on foreign investment holdings in RRSPs and RPPs makes venture capital funds unviably small or unviably diversified.

To understand the latter point, it is necessary to examine the economics of the venture capital industry. Scientists are usually highly specialized, and an expert in one branch of biochemistry may know little of another. Canada has too few innovators in any given area to justify a fund hiring appropriate in-house scientific specialists. Consequently, Canadian venture capital funds are less able than their U.S. counterparts to assess the viability of investment proposals. Canadian venture capital funds thus expose their investors to more risk than do U.S. funds. To compensate for this higher risk, Canadian funds must charge all innovators higher interest rates than U.S. firms. Consequently, Canadian innovators with viable innovations are better off seeking financing in the United States, where their ideas will be recognized as viable and where attractively priced funding will be available. Canadian innovators with unviable innovations will find the doors closed in the United States.

This selective migration thus worsens the average quality of innovations offered to Canadian venture capital funds.

The obvious solution would be to have Canadian based venture capital funds investing abroad to gain the necessary scale. "Sheltered" from global capital markets by the 20 percent rule, Canadian venture capital funds are either too small or invest in too many fields.

Indeed, there are several other reasons for thinking that openness to global markets should breed innovation. Greater returns to scale in innovation, more competition, more information flows, and more outside financial sources are all plausible. Unfortunately, studies on how actual openings to global financial and other markets affect the pace of innovation are scant. Trefler (1999) shows that the Canada-U.S. Free Trade Agreement (FTA) led to higher productivity in low-end manufactures, a reallocation of resources to high-end manufactures, and lower prices for consumers. Morck et al. (2000a) show that the passage of the FTA raised the share prices of independent firms relative to those controlled by old wealthy families. If their hypothesis of a "Canadian disease" caused by the economic dominance of old wealthy families with vested interests in the *status quo* and against innovation is valid, the FTA would appear to have disturbed that dominance, at least to some extent.

DOES HUMAN CAPITAL ACCUMULATION AFFECT THE PACE OF INNOVATION?

HUMAN CAPITAL IS THE KNOWLEDGE AND SKILLS HUMANS carry around in their heads that makes them valuable to an economy. The concept was advanced by Becker (1962), who regards human capital as a critical input to production as well as innovation.

There is a clear relation between a country's stock of human capital, usually measured by the educational achievements of its population, and per capita national income (see Mankiw, 1995). The average citizen of a high-income country is better educated than the average citizen of a low-income country. One interpretation of this is that educated citizens make a country rich. But another might be that rich countries spend more on education.

Barro (1991) and Barro and Lee (1996) address this issue by showing that a nation's economic growth is significantly related to its pre-existing stock of human capital, measured by the level of education of its citizens. This finding is consistent with the notion that a higher level of human capital causes per capita GDP to grow more rapidly. Fagerberg (1994) surveys empirical studies on the importance of "technology gaps" for differences in economic growth across countries. He finds a consistent pattern that lagging countries can converge toward higher income countries, but only if they have the "social capability" —

a large number of people capable of managing the necessary resources, including investment, education, and R&D. He argues that investment in education is an important complement to economic growth.[6]

It is also possible that human capital is valuable if it lets a country's businesses understand and exploit technology developed elsewhere. For example, Van Elkan (1996) develops a model of an open economy in which the stock of human capital can be augmented by either imitation or innovation. In her model, productivity at imitation depends on the difference between the body of world knowledge and the country's stock of human capital.

The wealth of empirical evidence on the importance of human capital as a determinant of innovation and economic growth has led theorists to design numerous models of this linkage. For example, Eicher (1996) models how the interaction between endogenous human capital accumulation and technological change affects relative wages and economic growth. Roy (1997) focuses on how the quality of human capital should theoretically affect the pace of endogenous technological progress and a model economy's long-run growth rate. He presents arguments supporting the view that the optimal policy might be to over-invest in human capital.

However, human capital and physical capital appear to be complements rather than substitutes in most firms. Ochoa (1996), using country-level OECD data for 1971-87, finds that physical capital accumulation in a manufacturing industry boosts that industry's long-run growth rate when it intensively employs full-time research scientists and engineers. Thus, the data are consistent with the view that R&D effort positively influences the marginal product of capital, such that diminishing returns do not necessarily moderate the positive effects of rapid capital investment.

Thus, human capital, as measured by educational achievement, appears to determine the pace of innovation of an economy.

Do Checks on Inequality Affect the Pace of Innovation?

We have argued above that growth through innovation leads to "winner-takes-all" outcomes and thus may increase income inequality. Canada has a strong, though recent, tradition of income equalization. Thus, one has to question whether income equalization affects innovation.

Bound and Johnson (1992) present evidence that the ratio of the average wage of a college graduate to the average wage of a high-school graduate rose by 15 percent in recent years. Murphy et Welch (1992) find that, in 1979, the hourly wage of a college graduate with fewer than five years of work experience was 30 percent more than that of a high-school graduate with similar experience.

By 1989, this premium had soared to 74 percent. The education differential rose most sharply among inexperienced workers, and experience *per se* appears to have become more valuable to employers. Davis (1992) found that between 1979 and 1987, the ratio of weekly earnings of males in their forties to weekly earnings of males in their twenties increased by 25 percent. Blackburn et al. (1990) find concordant results.

In the media, the growing earnings disparity in some developed countries is often attributed to freer trade. Economic theory formalizes these arguments into three related effects. First, increased trade with developing countries with large, unskilled labour forces should drive down the value of unskilled labour in developed economies. This is referred to as the Stolper-Samuelson effect in neoclassical economic theory. Second, technology transfers to developing countries should raise the productivity of unskilled labour in these countries. This should further increase the world's supply of unskilled labour-intensive goods, further driving down the price of unskilled labour in developed economies. Third, firms in developed economies, where the comparative advantage lies with capital and technology, should invest in capital-intensive production and should direct R&D toward improving the productivity of capital. This decreases the demand for unskilled labour in developing countries, again lowering unskilled workers' wages.

Despite the simple and elegant predictions of these theories, the empirical evidence on the causes of relative wage changes in the United States presents a more complicated picture, with new technology, not trade, as the critical element.

Berman et al. (1993) find little role for trade, while Bound and Johnson (1992) find that trade played basically no role in America's wage changes in the 1980s. Instead, they ascribe these changes to technological change and changes in unmeasured labour quality.

Lawrence and Slaughter (1993) focus instead on the price behaviour of traded goods, and find no evidence that the relative prices of goods that use production labour intensively have declined. From this evidence, they conclude that relative U.S. unskilled wages have not been driven down by competition from unskilled workers abroad (that is, by a Stolper-Samuelson effect). As noted above, they instead find a positive association between the growth of total factor productivity and the intensive use of high-skill labour, and that this effect is much larger than any conceivable Stolper-Samuelson effect.

Edwards (1993) criticizes the empirical literature on the relationship between trade orientation and economic performance, and expresses the view that many cross-country studies lack rigorous microeconomics-based, theoretically sound hypotheses to test. This is an almost epistemological argument. The "scientific method", as taught in the ninth grade, requires a hypothesis, a test, and a conclusion. Yet, much progress in science and economic theory involves making up explanations for observed empirical regularities. Gambardella (1995) argues that much industrial innovation arises from trial and error experiments. To varying degrees, this process is guided by a rational understanding of the phenomena under investigation. Similarly, economics is at too early a stage of development for us to trust our existing theories in too much detail.

Overall, the above findings accord well with the view that the pace of innovation has accelerated, and that it has increased the demand for high-skill workers and driven up their wages. Given the accelerated pace of innovation, the wages of unskilled workers would have fallen relatively regardless of the degree of protectionism in place. As noted above, Morck and Yeung (1992) argue that access to very large markets raises the returns successful innovative firms earn from their investments in new technology. This creates a corporate lobbying constituency for free trade, in opposition to the traditional protectionism of non-innovative firms and organized labour. Freer trade may thus result from the increased political influence of innovators.

INNOVATION AFFECTS THE RETURN TO SKILLED LABOUR

LAWRENCE AND SLAUGHTER (1993) ARGUE that faster innovation could be associated with increased inequality in two ways. One possibility is that technological change has been "biased" because it has increased the demand for some inputs, namely highly skilled and experienced employees, and decreased the demand for others, namely unskilled and inexperienced workers. Another is that technological progress has been faster in skill-intensive industries.

The first hypothesis is supported by Berman et al. (1993), who find a strong correlation between skill upgrading within industries and increased spending by firms on computers and research. They conclude that technological change that saves low-skill labour is the most likely explanation for the shift in demand toward high-skill workers. Bartel and Lichtenberg (1991) find that industries that use new technologies pay a wage premium.

Lawrence and Slaughter (1993) find that productivity growth has been significantly higher in industries that employ a higher ratio of high-skill labour to low-skill labour. This is consistent with the argument presented earlier: that the pace of innovation is accelerated if workers have more human capital. Technological progress is concentrated in skilled-labour-intensive industries, and this explains the higher wages of skilled workers relative to unskilled workers.

HOW MUCH INEQUALITY IS NECESSARY?

THE PREVIOUS TWO SECTIONS ARGUE that the increased inequality in the United States and some other countries is most likely the result of technological change, rather than trade. Of course, a higher return to innovation due to access to larger markets may have accelerated the development of new technologies.

Technological progress is itself endogenous. Market forces direct it, and trade barriers, political constraints and other obstacles can reshape these forces.

Is this inequality necessary for innovation to be rapid? Is some sort of social democracy an alternative to the inequality a capitalist economy produces by its ongoing creative destruction? For some time, it looked like various countries had found ways to avoid inequality and yet post healthy growth.

A frightening view of the relationship between inequality and innovation is evident in recent work on Sweden's economic problems. Until recently, many economists would have pointed to Sweden as an example of egalitarianism that works. Sweden's low unemployment, high income, and high growth led economists everywhere to look to that country for ideas. This interest did not last. In the 1990s, Sweden's "true" unemployment rose well above 10 percent (Sweden's official unemployment rate is measured very differently from that of other countries). Its public debt ballooned, and its industrial production and retail sales fell 10 percent below what they were a decade ago. Sweden's high-school graduates face an unemployment rate of close to 25 percent.

Freeman et al. (1997) present explanations by ten American and ten Swedish economists, generally working in two-person teams, of how and why Sweden ended up in such a state.

First, they offer evidence that Sweden's welfare state really did cause its superb economic statistics in earlier decades, not ethnic homogeneity or other cultural factors. But some of this is done with mirrors. Sweden's high taxes and its use of civil servants to provide free child-care, free care of elderly people, etc. encouraged both spouses to work. Often, one of the spouses ended up working for the government delivering such services. This greatly inflated GDP, but may have increased people's well-being only slightly, or may even have decreased it.

Second, the evidence shows that Sweden's high taxes and generous public services have caused employees there to work fewer hours and less productively. Welfare losses rose to 40 percent of revenue.

Third, Sweden's national tripartite wage agreements allowed unions to shrink the gap between high-skill and low-skill pay. This led firms to use more cheap skilled labour, and underlay Sweden's boom as firms rapidly expanded their high-skill-intensive lines of business. Unskilled labour was absorbed mainly by the public sector. But the low wage differential between skilled and unskilled labour reduced peoples' incentives to acquire human capital. By the 1990s, frustrated high-skill workers and their unions were defecting from the tripartite wage-setting arrangement, and shortages of high-skill workers slowed economic growth.

Freeman and Needels (1991) find that the wage differential between college and high-school graduates increased only slightly in Canada during the 1980s. They conclude from this that the wage divergence in the United States was not the result of "an inexorable shift in the economic structure of advanced capitalist countries," but a reflection of "specific developments in the U.S. labour market." Their conclusions may have been premature, for Williamson (2000) shows that Canada is now experiencing a brain drain of its most talented people to the United States where their after-tax wages are substantially higher. Hatton and Williamson (1994) use immigration data from 1850 to 1939 to show that people migrate to wherever their human capital is most valuable, so Canada's brain drain should continue until the value of human capital rises in that country.

Schumpeter's view of innovation as a winner-takes-all process, and the evidence discussed above of how important human capital may be in accelerating innovation, suggest that Freeman and Needels (1991) might be wrong. If so, increasing wage inequality may be "an inexorable shift in the economic structure of advanced capitalist countries" associated with an increasing pace of innovation.

However, there are worse things than income inequality, and innovation may help head them off. Szostak (1995) argues that the Great Depression of the 1930s was due to a sharp decline in the pace of technological innovation in that decade and the years immediately before it. Intriguingly, Caves et al. (1984) find that the share of industries dominated by a few major players declined between 1905 and 1929.

Undeniably, fostering innovation can lead to more inequality. Property rights protection may appear to enhance the incentive to innovate and yet in reality increase income inequality for no good results. For example, Mutti and Yeung (1996, 1997) show that, in the United States, protecting domestic firms from import competition with property rights protection laws results in protecting the affected U.S. firms' profits but hurting the affected industry's R&D race intensity.

Yet, inequality may be an indispensable mechanism for directing labour and human capital investment to where it is most needed. High incomes attract talent, and talented people enjoy a great deal of mobility.

We do not know what level of inequality is necessary. However, we can say something about the type of inequality we can target for removal and that which is necessary for creative destruction to operate. Using country-level data on the concentration and type of wealth, Morck et al. (2000b) find that substantial wealth in the hands of old established families is associated with low levels of economic growth and a scarcity of innovation. In contrast, inequality due to self-made wealth is associated with more innovation and higher economic growth. Perhaps social agendas aimed at greater equality should focus on inherited wealth, not high incomes.

DOES GOVERNMENT POLICY DETERMINE INNOVATION?

THE FACT THAT INNOVATION IS BASED ON INFORMATION, and that information has unique properties that cause market solutions to be suboptimal in many cases, suggests a possible role for government in information generation and innovation.

HOW WELL DOES THE FREE MARKET DIRECT INNOVATION?

KOPPEL (1995) PRESENTS AN OVERVIEW of *induced innovation theory*. This is the view that consumer demand and the supply of different inputs determine the course and speed of innovation. An example is that the falling price of fertilizer relative to that of rice led to the development of highly fertilizer-responsive rice varieties, which induced the "green revolution".

Koppel's book assumes that the free market can allocate funds to innovations that make economic sense and divert funds away from those that do not. He questions whether political and ethical agendas should supersede economic determinants of the direction of innovation. This is a difficult issue because the theoretical concept of "efficiency" used by economists to justify "market solutions" is essentially a static concept. It fits poorly into the dynamic context of innovation, productivity improvement, and economic growth. For this reason, the present paper has concentrated on empirical rather than theoretical studies.

The private sector has a track record of funding successful innovations over several centuries, and the increasing pace of innovation suggests it may be getting steadily better at this task. Kealey (1996) points out that, throughout the nineteenth century, British academics bemoaned the lack of government support for research and looked enviously at their French counterparts who were awash in state subsidized research schemes. Yet, the British economy outpaced the French economy by every measure of growth during that century, and British scientists such as Charles Darwin, Henry Cavendish, Humphrey Davy, Michael Faraday, Robert Hooke, and others performed privately-financed path-breaking basic and applied research. Kealey argues that, though French scientists did important work, their research had little economic impact because the free market did not guide it. He adds that Britain only fell behind in the mid-twentieth century, when it switched to the French system of *dirigism*.

In contrast, governments seem poor at allocating money for innovation. Until recently, Japan's Ministry of International Trade and Industry (MITI) was considered as the sole exception. MITI was thought to have chosen winners early on, financed them generously, and created globally competitive Japanese firms. We now know that this is entirely false. Beason and Weinstein (1996), in the first statistical study of MITI's allocation of capital, find that

MITI mainly subsidized losers, and that firms that received MITI subsidies tended to perform worse afterwards.

THE DYNAMIC COSTS OF POLITICAL RENT-SEEKING

THE PROBLEM DOES NOT SEEM TO BE A GENERAL INABILITY to recognize valuable innovations, though Ostry and Nelson (1995) find evidence of what they call a "high-tech fetishism" in many government programs aimed at stimulating innovation. Rather, the deeper problem seems to be a tendency for government subsidy programs to be captured by special interests. Murphy et al. (1991) develop a model of Schumpeterian innovation and dynamic efficiency, similar to that of Romer (1986), in which entrepreneurs can invest in R&D to raise the productivity of the economy's production process. However, in this model, entrepreneurs have an alternative investment possibility. Murphy et al. (1991) let their entrepreneurs choose between investing in productivity enhancing innovations and investing money in influencing political decisions to increase their future profits. These investments in political connections are called *political rent-seeking*, and from the prospective entrepreneur's viewpoint they are much like investments in innovation. The entrepreneur pays up front and receives returns stretched across many subsequent years.

Murphy et al. (1991) point out that if political rent-seeking is more profitable than investment in real innovation, rational entrepreneurs will spend more money influencing politicians and less doing research into enhancing real productivity.

Political rent-seeking is inefficient in a dynamic sense because it is a zero-sum game. The return to lobbying for favourable discriminatory government policy is extracted from other segments of the economy in the form of taxes, higher consumer prices, restraints on trade, and/or artificially restrictive regulations.

In an economy where innovation is uniformly more profitable than political rent-seeking, productivity will grow. In an economy where the reverse is true, productivity will progress slowly or not at all. Indeed, it may fall as ever more resources are diverted into political rent-seeking.

Murphy et al. (1991) consider the relative number of engineers and lawyers who graduate from a country's universities as a measure of the value of a career in innovation relative to one in political rent-seeking. They find a clear, statistically significant correlation: countries with more law graduates grow more slowly, countries with more engineering graduates grow faster. This approach is consistent with Geroski (1994), who finds that innovations from the engineering sector of the U.K. economy have a bigger long-run impact than those from other sectors.

Baumol (1993) independently developed a similar theory from historical comparisons of the rewards to innovators in different countries at different times and their economic growth rates. He argues that ancient and medieval societies suppressed innovations by denying innovators any rewards. For example, the innovation produced by a peasant belonged to his hated feudal lord. Thus, political rent-seeking is typically the only innovative activity in these societies. A few centuries ago, as property rights began to change to let innovators profit from their innovations, the pace of innovation and economic growth shot upward.

Lenway et al. (1996) explore the relationship between political rent-seeking and innovation at a micro-economic level with an analysis of the U.S. steel industry in the 1970s and 1980s. U.S. steel firms were arguably inefficient relative to plants elsewhere that used more modern technology. Some American steel firms invested heavily in R&D, while others concentrated on political lobbying. The would-be innovators were strong, competitive firms — mainly new mini-mills. The lobbyers were financially weaker, old firms. Extensive and effective trade barriers were erected in 1984. In subsequent years, U.S. steel makers reduced R&D spending, increased CEO compensation and increased the pay of senior workers. R&D-intensive firms had abnormal probability of leaving the steel business, either due to bankruptcy or to strategic shifts to other businesses. On the news of these barriers, R&D-intensive U.S. steel makers' stocks fell and those of active lobbyers rose. Lenway et al. (1996) argue that these findings are supportive of the theory of Murphy et al. (1991).

Finally, pervasive rent-seeking can lead to subsidy wars, where different governments offer increasingly generous subsidies to encourage firms to locate in their jurisdiction. These subsidy wars would appear to deplete public coffers to little purpose. Consequently, Ostry and Nelson (1995) argue for the harmonization of R&D subsidies.

In summary, political rent-seeking becomes more profitable than investment in productivity enhancement as government grows larger. As Lindbeck (1987) says, "The problem with high tax societies is not that it is impossible to become rich there, but that it is impossible to do so by way of productive effort."

As voter awareness of the costs of rent-seeking grows, governments are no longer trying to pick winners, and instead are focusing on creating a congenial economic environment for innovation. Thus, we have liberalization, deregulation, and efforts to increase the efficiency of government to provide the same public services at lower tax costs.[7] Systematic studies of the impact of such policies on innovation are needed to assess these newer approaches.

Does Government Policy in other Areas Affect the Pace of Innovation?

THE ANSWER APPEARS TO BE "YES", though much more research is needed to confirm this. Monetary and fiscal policies affect the taxation of financial intermediaries and the provision of financial services (Bencivenga and Smith, 1992;

Roubini and Sala-i-Martin, 1995). Of course, the development of a country's financial system has been shown above to be important in fostering innovation. Legal systems affect financial systems (La Porta et al., 1997b), so legal systems may also affect the pace of innovation. Political changes and national institutions also critically influence financial development (Haber, 1991, 1996), so these may also affect a country's ability to innovate.

Rosenberg and Birdzell (1986) point out that peasants in the western world were probably at least as impoverished as their peers elsewhere in 1600. They muster a vast amount of historical evidence to argue that legal and financial developments are critical to understanding why western countries *per capita* incomes have risen so sharply against the incomes of people elsewhere in the world.

Regulatory regimes may have a particular influence on innovation. Regulations should not be flexible, for flexible regulations render political rent-seeking more lucrative. Politicians' pressure is more effective on regulators who have wider discretion. But past economic advisors have convinced governments to focus on static efficiency questions, and only recently have they begun to emphasize dynamic economic efficiency. Their advice was sound, given what economists knew at the time and given a slower pace of innovation.

But ignoring dynamic efficiency issues is now becoming very costly. Hausman et al. (1997) stress that U.S. regulations, "as currently implemented, may well be unable to keep up with the fast-paced changes in telecommunications technology." They find that consumers' losses caused by lengthy regulatory delays that kept voice messaging and cellular services from the market were "in the billions of dollars per year". They conclude that the Federal Communications Commission "focused on static cost-efficiency questions and failed to account for the demonstrated large gains in dynamic economic efficiency that arise from new investment."

The bottom line is that we need regulations that are designed for a changing economy, but that are well enough drafted to be applied consistently without hampering innovation.

PUBLIC SPENDING ON HUMAN CAPITAL AND INNOVATION

BUT THE OUTLOOK ON GOVERNMENT INVOLVEMENT in innovation is not uniformly pessimistic. Link (1996) deduces that government-industry partnerships often have high value added. His unique contribution is a model of out-of-equilibrium economies with explicit adjustment mechanisms that assign a special role to credit creation. The applicability of this approach to real political economy is untested.

Ochoa (1996) finds that the number of research scientists and engineers employed by the government and higher education establishments is positively associated with long-run output growth across OECD countries, even while controlling for the number of research scientists and engineers employed by each manufacturing sector.[8] This is consistent with the evidence presented above on the fact that innovative clusters are primarily labour market phenomena.

Also, human capital can be divided into firm-specific, industry-specific, and general human capital. Firm-specific human capital is knowledge that has value mainly to one firm. Knowledge about a firm's own peculiar computer system is an example. Industry-specific capital and general human capital are knowledge valuable to any employer in an industry, and to any employer anywhere, respectively. Examples are advanced training in petroleum engineering and in public speaking. The former is of value to any oil company, the latter to companies in many industries. A firm often invests in its employees' firm-specific human capital because it is then justified to pay higher salaries to its employees than competitors could offer them, and so binds employees with human capital to itself. Firms are reluctant to invest in industry-specific or general human capital, because the employee can leave at any time, taking his expensive training with him or her to another firm. Government spending on people's human capital development might therefore be a plausible way to reduce inequality and bolster innovation at the same time.

What sorts of investment in what sorts of human capital government might best provide is slowly becoming evident from the data. Many of the studies discussed above indicate that human capital associated with education is valuable to employers, and generates higher wages for its owners. Friedlander et al. (1997) find that retraining programs for unskilled, displaced workers often do not work well. The greatest success is with mature women. The least is with young people. Mature men are in the middle.

Can government intervene in the economy to assist people in developing their human capital? Is public support for human capital development the preferred approach to promoting investment in human capital? "Market failures" create a case for such public involvement. But economists, and the public too, are increasingly cognizant of "government failure" due to general inefficiency, political rent-seeking, and other problems of public-sector governance. Given the increasing premium associated with a higher quality university education found by Hoxby (2000b), inefficiency and waste in the education sector is of concern. Hoxby (2000a) finds that voucher systems and other forms of competition improve the quality of public schools. Ways of increasing competition between publicly-funded universities warrant perhaps more attention.

BASIC RESEARCH IN THE PUBLIC DOMAIN

GAMBARDELLA (1995) DESCRIBES how advances in genetics, molecular biology, computers, and instrumentation have rationalized drug discovery. A generation ago, pharmaceuticals innovation was done by trial and error, with thousands of molecules tested to reveal a few possible pharmacological activity. Some were related to existing drugs, others were simple gambles. Now commercial pharmacology uses a vast wealth of basic research knowledge in the public domain to direct research more intelligently, thereby increasing its financial returns. Most of this basic research has been publicly financed and conducted at universities or research institutes.

According to Gambardella, one result of this change is more openness about basic research done within pharmaceutical firms. Companies now want their in-house scientists to participate in conferences, publish papers, and share information with colleagues in universities and research institutes. This greater openness gives companies improved access to new developments but it lessens their control on internal information. Of course, research aimed at developing new products is still central to private-sector firms.

Gambardella also argues that this trend presages an expansion of research and licensing agreements between universities and pharmaceutical firms. He also predicts that, as firms attempt to direct or appropriate university research, concerns about academic freedom will grow.

Publicly available basic research would seem more necessary than ever. Again, however, problems of government failure loom large. Peer review and other time-honoured methods of allocating research funding are subject to capture by rent-seekers with connections. Bureaucratic inefficiency in large universities is widely acknowledged to be a serious problem.

HOW IMPORTANT IS GOOD GOVERNMENT?

LA PORTA ET AL. (1998) FIND THAT HONEST GOVERNMENT, sound securities laws, etc. are strongly related to a country's economic health. This is consistent with theoretical work by Buchanan likening countries to private clubs. Clubs that provide attractive services for their membership fees attract important and influential members. Similarly, countries that return valuable services for the taxes they collect can attract and retain people with highly developed human capital. Clubs that provide little value for their membership fees lose members, as countries that provide too little real value for the taxes they levy lose citizens. The first to go are those with valuable skills and expertise, for their human capital is welcome elsewhere. As an uncompetitive economy loses human capital, it falls further and further behind.

Thus, highly skilled Indians and mainland Chinese emigrate because those countries have numerous historical problems and deliberate political policies that frustrate people with skills, talent, or entrepreneurial ability who are not political insiders. Canada and the United States both benefit as recipients of this flow of human capital. The United States may benefit disproportionately if it is a more attractive political and economic environment for innovators than

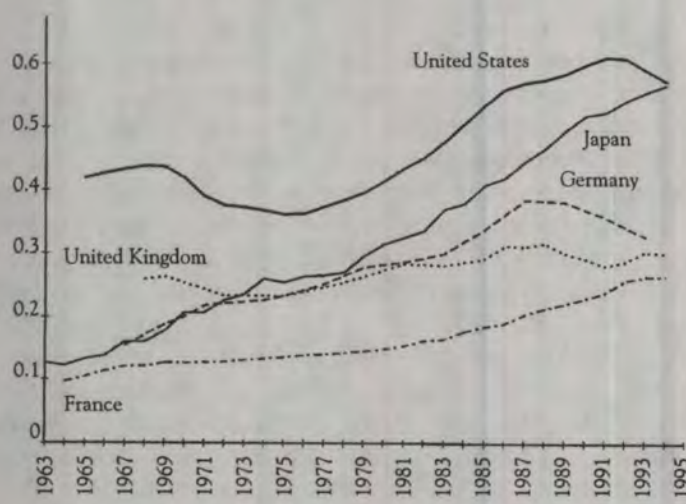
Canada, and so receives more of the most skilled Asians as well as an inflow of highly skilled Canadians.

In Canada, these issues have been muddied by debates about whether or not there is a net "brain drain"; see, for example, Zhao et al. (2000). The issue is not whether Canada's supply of human capital is growing or shrinking. Rather, the nub is whether the size and growth rate of Canada's overall stock of human capital relative to those of its major economic competitors, most notably the United States, is growing or shrinking.

Kortum and Lerner (1998b) document a sharp increase in the number of research scientists and engineers employed in business enterprises as a fraction of the labour force in the United States through the 1980s and 1990s. Their data, graphed in Figure 4, show a similar increase in Japan, but reveal that France, Germany and the United Kingdom had stocks of scientists and engineers, measured as a fraction of their total labour force, only half as large as those of the United States and Japan in 1995. The same data show that this gap has widened greatly since the late 1980s. If Canada's stock of scientists and engineers (or other skilled, talented or entrepreneurial people) is similarly low and declining relative to that of the United States, this could be a symptom of public policy dysfunction of considerable gravity.

FIGURE 4

RESEARCH SCIENTISTS AND ENGINEERS RELATIVE TO THE LABOUR FORCE (EMPLOYED IN BUSINESS ENTERPRISES)



Source: Kortum and Lerner (1998a).

Does government policy affect the pace of innovation? Dysfunctional government policies can doubtless impede innovation. Whether government can do more than get out of innovators' way is less clear. An active government policy is justifiable only to the extent that the government failure problems described above can be overcome. Work to clarify these issues is urgently needed.

CONCLUSIONS

COUNTRIES THAT SHOW MORE SIGNS OF INNOVATION are wealthier and grow faster. The same is true of companies. Innovative firms must be able to grow very large very quickly. Monopolies resulting from successful innovation are not necessarily bad from an economic standpoint. They are also likely to be temporary. Intellectual property rights prolong innovators' monopolies, and this is not always beneficial to society. Established, large firms have an advantage at incremental innovation, but small firms seem better at radical innovation.

State subsidy programs aimed at encouraging innovation within firms uniformly fail. They appear to encourage firms to become innovative only at extracting money from the government. This is rational if the program makes such behaviour their highest-return activity. Governments should also realize that lower taxes, both personal and corporate, are the simplest and most direct way to subsidize winners rather than losers.

Innovation raises the demand for high-skill workers and drives up their wages. Subsidizing education may therefore make sense.

Innovative firms appear to spontaneously form geographical clusters. Although many high-profile theories purport to explain this, the data seem most consistent with concentrations of skilled workers attracting firms that need them, and those firms attracting more skilled workers, in a positive feedback loop. If so, policies to create skilled labour, such as the Millennium Endowment Fund, would seem more defensible than overt or hidden subsidies to high technology enterprises. However, the danger of government failure weighs heavily across all activist policy options in this area.

Corporate governance also seems to matter. Many of the classical capital budgeting tools used by corporate managers work poorly in assessing the returns to innovation. Newer techniques that might be more appropriate are being developed, but are not in use in Canada to any significant extent. Corporate incentive schemes for innovative employees also seem successful.

Excessive equality has been shown to damage productivity and discourage people from acquiring skills. But excessive inequality is also a problem, for the established wealthy have a vested interest in preserving the *status quo*. Many traditional Canadian policies have the (perhaps) unintended effect of protecting inequality in dimensions that matter for innovation. These include Canada's high income taxes (which prevent innovators from getting rich), low taxes on inherited wealth (which preserve existing wealth concentrations), and a tradition of protectionism (which protects non-innovative, established firms from competition by foreign innovators).

Culture also matters. Respect for enterprising behaviour and the enforcement of business contracts seem central here.

Finally, the financial system matters. An efficient and competitive financial system helps innovative small players grow large quickly and displace established wealth. Existing large corporations, in contrast, seem poor at managing new ventures. Large, independent and scientifically sophisticated venture capital funds appear critical. Canada has no such industry at this time.

ENDNOTES

1 See "University Research and the Commercialization of Intellectual Property in Canada," a paper prepared for the Expert Panel on the Commercialization of University Research of the Advisory Council on Science and Technology, March 1999, Table 3.

2 Another example of a monopoly ignoring opportunities to innovate is Canada's cable industry, as described by Acheson et al. (1999). Canada was cabled earlier than the United States. But Canadian regulation focused on the creation and protection of rents. Outsiders were not allowed to innovate. Insiders did not want to cannibalize their rents. Innovation ultimately occurred in the United States. We are grateful to Donald G. McFetridge for suggesting this example.

3 For details, see Tobin and Brainard (1977).

4 See also Gomes-Casseres (1997).

5 For details of these and related techniques, see any introductory textbook in corporate finance.

6 One possible dissenting note is Ochoa (1996), who finds the rate of growth (as opposed to the stock) of a country's human capital not related strongly to overall economic growth. One way to reconcile Ochoa's finding with the mainstream results quoted in the text is to hypothesize a substantial lag between the time a country's stock of human capital rises and the time its per capita income rises in response. Further work is required on this point.

7 See Morck and Yeung (1995) for a further explanation of this point.

8 Gu and Whewell (1999) show that the academic sector in Canada accounts for a higher share of national R&D investment than universities in other OECD countries, and yet R&D spending by universities as a share of GDP in Canada is among the lowest in the G-7 countries. About 40 percent of Canadian universities' R&D spending is funded by the federal and provincial governments.

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Part III
Investment and Productivity

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12

Investment and Productivity – Review of Recent Literature

INTRODUCTION

MOTIVATION FOR THE STUDY OF PRODUCTIVITY is not hard to find today. Real incomes in Canada did not grow much in the 1990s and, after decades of catching up, they declined relative to the United States in the last decade. Sharpe (1999) estimates that Canadian incomes were roughly 75 percent of U.S. incomes in 1999. As Figure 1 illustrates, Canada's relatively poor recent performance looks even worse when more countries are added to the comparison, as other G-7 nations continued to close the gap with the United States while the gap widened for Canada.

When real incomes fail to grow as expected it seems natural to look for levers that can raise living standards and the one that draws the most attention is productivity. As Harris (2002) succinctly states: "Over long periods of time, productivity is the single most important determinant of a nation's living standard or its level of real income." While absolute income levels should be the primary focus, income relative to the United States seems to be the benchmark that causes the most concern in Canada. Sulzenko and Kalwarowsky (2000), for instance, use this measure to provide a perspective on what is at stake: "Raising productivity offers Canada the largest upside potential (relative to increasing labour input).... To illustrate, of the $7,500 Canada-U.S. per capita income gap, a full $6,200 is accounted for by Canada's significantly lower level of productivity while only $1,300 stems from the higher effective rate of employment in the United States."

This section of the book deals with the more specific topic of investment and productivity, and here too motivation is not hard to find. In a recent summary of the evidence for G-7 countries, Jorgenson and Yip (1999) indicate that "Investments in tangible assets and human capital now account for the predominant share of economic growth in the G-7 countries and also explain the predominant share of international differences in output per capita."

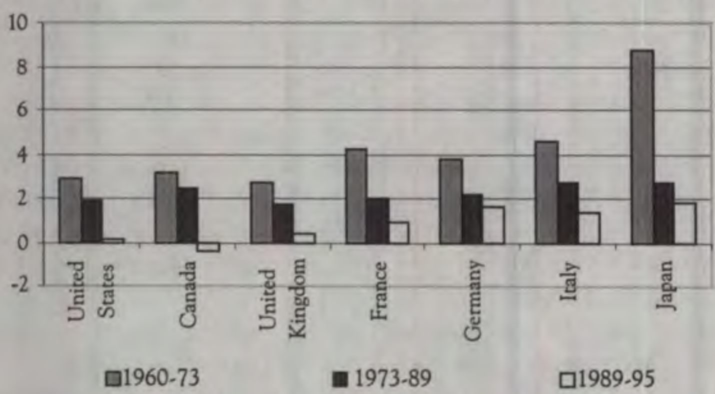
The claim that a strong link between investment and productivity exists is intuitively plausible: investment provides the tools with which Canadians produce output — the more tools we have to work with, the more we can produce. Moreover, the evidence summarized by Jorgenson and Yip seems to imply a strong empirical confirmation of this intuition.

But while the intuition is compelling and supporting evidence exists, some doubts have been expressed. For instance, Blomstrom, Lipsey and Zejan (1996) allow for the possibility that the link between investment and growth actually goes the other way (i.e. growth leads to investment) and provide evidence to support this alternative hypothesis. In addition, Power (1998) examines plant-level data and concludes that " . . . there is virtually no observable relationship between investment and productivity or productivity growth."

In line with some of this contradictory empirical evidence is a supporting intuition: While investment improves productivity, capital market imperfections keep firms from investing until they generate sufficient internal resources to pay for the capital. In other words, despite the existence of capital markets, some firms act as if they did not exist. These firms invest when they can 'afford' to do so in a cash-flow sense. So, while investment may increase productivity, some of the contradictory evidence results from the fact that investment follows cash flow increases.

FIGURE 1

GROWTH IN OUTPUT PER CAPITA



Source: Jorgenson and Yip (1999).

Thus the current state of knowledge leaves important questions unanswered. What is the appropriate way to measure investment? How strong is the link between investment and productivity growth? To the extent that there is a link, does it imply a role for government in improving welfare?

Even if one held the view that there is a link between investment and productivity, the extent to which policy can work through this link is, not surprisingly, subject to debate. On one side, there are those who view investment as a channel for producing externalities that are not internalized by market prices. In this world, government policy aimed at subsidizing private returns will increase welfare. On the other side, there are those who feel that markets, left to their own devices, produce investment levels that efficiently reflect the preferences of savers and investors. A third view, related to the first, is that investment decisions are driven largely by capital market imperfections. In this view, investment options can only be exercised when capital market imperfections are overcome or when firms generate enough internal financial resources to support an investment. Overcoming market imperfections in turn requires the development of institutions, specialized contracts, and/or more efficient governance mechanisms.

This chapter offers a partial review of what is known about investment and productivity. The discussion rests on the two papers presented in this part of the book: *Investment and Productivity Growth: A Survey from the Neoclassical and New Growth Perspectives*, by Kevin J. Stiroh, and *Does Under-investment Contribute to the Canada-U.S. Productivity Gap*, by Edgar R. Rodriguez and Timothy C. Sargent.

A clear indication that this is an interesting and important research area is given by the fact that the two papers largely come to different conclusions about the role of investment in explaining productivity. Stiroh very usefully casts his survey in light of the distinction between the neoclassical models, where returns to investment are captured by the private agents making investment decisions, and the endogenous growth model literature where, as characterized by the author, some returns are not captured by investors. Stiroh ends his overview of investment and productivity by stating that " . . . one conclusion appears universal: broadly defined investment is the crucial factor that increases productivity, generates economic growth and raises living standards."

Rodriguez and Sargent examine the specific question of whether the Canada-U.S. investment gap can be explained by the productivity gap between the two countries. They recognize that "Canada significantly underinvests in R&D and in machinery and equipment", but the authors "do not agree that these investment gaps necessarily explain much of the Canada-U.S. productivity gap." They concede, however, that " . . . something must explain the gap, and that something might be related to underinvestment of some kind."

So, while the two papers provide a useful overview of recent research in the field, they draw somewhat different conclusions, suggesting more work is needed to understand the investment/productivity link.

In this introduction, we provide an overview of work done in this area and discuss a number of research issues that have either not been explored in detail or not been related directly to the issue of investment and productivity.

In the next section, we begin with a more elaborate discussion of what productivity (the focus of these studies) actually is, i.e. we look at how productivity could and/or should be measured. This is followed by a conceptual outline of the link between investment and productivity. Empirical research into the investment/productivity link has yielded a number of important findings. We discuss three of these findings: i) the importance of the specific measures of investment used; ii) the importance of human capital; and iii) the importance of R&D. We then look at the trends that have emerged. Special attention is paid to investment in machinery and equipment, as well as investment in the manufacturing sector. Finally, we discuss an alternative view of the investment process that emphasizes the importance of market imperfections.

INVESTMENT AND PRODUCTIVITY

LINKING INVESTMENT TO PRODUCTIVITY requires that we be clear about what we mean by both terms. Sulzenko and Kalwarowsky (2000) follow common practice by defining productivity as "the efficiency with which people, capital, resources and ideas are combined in the economy." It is difficult to disagree with this definition as a guiding principle, yet its application requires a more specific definition of inputs, outputs and efficiency.

In practice, the construction of a productivity measure starts at the most general level with a ratio of output per unit of input. The ideal output measure would be some index of the satisfaction or utility achieved by participants in the economy. Input measures typically include labour and various forms of capital.

THE BASIC APPROACH

A COMMONLY USED METHOD for relating output to investment and labour is depicted by the neoclassical model:

$$Y = Y(S,N,O),$$

where Y is the flow of output over some time period, and S and N are the flows of capital and labour inputs, respectively, over the same period.

The output measure widely used in the macro-economics literature is GDP, but there has long been dissatisfaction with this measure. As a result, the development of new measures of economic and social well-being has become a growth industry, with little evidence that there will ultimately be widespread agreement on a particular index. Sharpe (1999) reviews this literature and the relationship between GDP and other measures of welfare. Though not all measures track GDP, they are all related to a substantial part of GDP. Hence, GDP is commonly used as the output measure in these studies.

Typically, the flow of capital inputs is simply proxied by some quality-adjusted stock of capital, *K*, in place at the time. Investment is related to output growth by being defined as the rate of change of the capital stock over that period of time. *N* is the labour input, typically measured by hours of work or number of workers supplied (which can differ from the number of hours worked). *O* refers to other factors. A common interpretation of empirical estimates of O is that it captures technological progress, but it will also reflect such factors as cost shocks or measurement errors due, for example, to changes in interest rates or risk premia not included in the measure of capital services.

Specific technological assumptions are captured by a production function, $F(K,L)$, that relates physical inputs of capital (proxied by the capital stock) and labour services used, to output. Multifactor productivity is defined as an index, *A*, of output to a weighted sum of inputs:

$$A \equiv \frac{Y(S,N,O)}{F(K,L)}.$$

For a specific technology, output can then be related to capital, labour and other factors as captured by *A*:

$$Y = A^{*}F(K,L).$$

Rather than deal in levels of output, most researchers are interested in explaining growth in output per capita, per employed worker, or per hour worked. The result is the following familiar transformation of the neoclassical model:

$$(1) \quad \Delta \ln y = v_k \Delta \ln k + v_l \Delta \ln l + \Delta \ln A,$$

where lower case letters indicate aggregate amounts divided by the measure of labour supply.

Equation (1) is presented in Stiroh where its importance to research in the area is emphasized: "The appealing simplicity and intuition of this neoclassical framework has made it the backbone of applied and theoretical work on productivity and economic growth."

Two common uses of the shorthand term 'productivity' seem to be captured in this relationship. Often, as for instance in Stiroh's paper, productivity seems to refer to labour productivity, the left-hand side of Equation (1). In other cases, as for instance in Jorgenson and Yip (1999), productivity is used to refer to the Solow residual, A. Unless otherwise indicated, we will use productivity to refer to the growth in output per unit of labour input.

The relationship between productivity and capital is clearly set out in Equation (1) where the coefficient v_k captures the relationship between the capital input and productivity. However, under the usual neoclassical assumptions of competitive markets and decreasing returns to scale, there is little room for this equation to explain increases in standards of living. All increases in productivity come exogenously from gains in multifactor productivity.

Rodriguez and Sargent contrast the neoclassical approach with the endogenous growth models. They show how these models explain productivity as the result of optimizing decisions made by private agents, as opposed to exogenous technical progress. The source of growth can be an increase in various types of investment, the level of human capital investment, or the quality of R&D expenditures.

The considerable body of empirical research focused on this productivity/investment relationship has produced, among others, the following results.

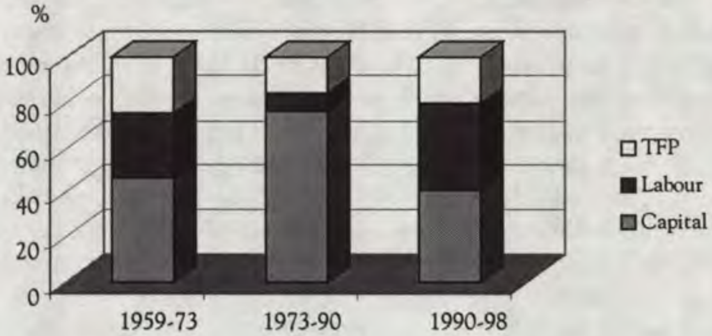
The Importance of the Definition of Investment

AT A GENERAL LEVEL, investment is defined as " . . . the commitment of current resources in the expectation of future returns."[1] While seemingly straightforward, this definition is in fact ambiguous and the work surveyed by Stiroh shows that the ability of investment to explain output depends critically on the specific way in which investment is defined empirically. Moreover, Rodriguez and Sargent argue that Canada-U.S. comparisons can be misleading if based on inappropriate measures of capital.

Solow (1957) defined investment generally and found that it had little explanatory power. In his early study, almost 90 percent of output was related to technological progress. As a result, numerous and more specific characterizations of investment were developed and found to explain a greater component of productivity. For instance, in a very recent study Jorgenson and Stiroh (2000) use 57 different types of private investment in their examination of U.S. productivity. Figure 2 shows that with these finer measures, investment accounts for about 48 percent of U.S. productivity growth, labour accounts for 34 percent, while only 18 percent is explained by total factor productivity.

FIGURE 2

COMPONENTS OF U.S. GROWTH



Source: Jorgenson and Stiroh (2000), as reported in Stiroh (2000).

Jorgenson and Griliches (1967) initiated a line of research intended to deal with the heterogeneity of capital. This approach produces constant-quality indexes for both labour and capital that explicitly adjust for a number of characteristics. An important characteristic is the user cost of capital of the asset. To see how the user cost of capital and the investment process are linked, consider a corporate manager who makes investment decisions in order to maximize the market value of the firm. That is, the manager solves the following problem in evaluating an investment opportunity:

$$\max_{I} \; V = \sum_{t=0}^{T_i} \frac{y_{it}(I, L)}{(1 + r_{it})^t} - p_{ai}(I) ,$$

where V is the net present value (NPV) of the investment opportunity, $y(I,L)$ is the technology that converts a quantity of investment (I) and labour input (L) into future output; r_{it} is the user cost of capital, T_i is the life of the investment project, and $P_{ai}(I)$ is the present cost of the investment decision. It is important to note that each project is associated with a required rate of return, r_{it}, that reflects the timing and risk of the cash flows, y_{it}. Consequently, productivity, the ratio of output (y) to capital and/or labour, will only be a consistent measure of efficiency if it reflects the specific required rate of return of a project.

Hence, when evaluating the aggregate contribution of capital to output, each unit of investment should be adjusted by the required return of the specific investment made. Jorgenson and Yip (1999) discuss the procedure by which this is done as well as the appropriateness of using the required return as opposed to the market value (V) of the asset. By taking this approach and adding other complexities such as a depreciation rate and the tax treatment of investment, constant-quality indexes are computed.

The adjustment for the cost of capital can also play a central role in international comparisons. Rodriguez and Sargent point out that differences in measured productivity between Canada and the United States would be expected if there were differences in interest rates between the two countries. However, it should be recognized that, even if a single worldwide interest rate prevailed, the average cost of capital (and therefore measured productivity) in one country might differ from that in another country simply because of differences in risk. In this case, there will be differences in measured productivity despite perfectly efficient investment decisions — the ratio of output to investment must be higher for riskier investments.

Another important characteristic of investment is the age of the capital stock. Rodriguez and Sargent provide evidence suggesting that the age of the average capital good in Canada is somewhat lower than in the United States, though the age of machinery and equipment is quite similar.

THE IMPORTANCE OF HUMAN CAPITAL

CLEARLY, THE ISSUES OF HETEROGENEITY that have been recognized in the study of physical investment also arise when examining the labour input. In fact, training and education are conceptually consistent with the notions of investment outlined above. One of the primary differences is the ability (or inability) of agents to write contracts and the impediments that imperfect contracts impose on the creation of a market for a given investment.

The research surveyed by Stiroh shows that heterogeneous human capital seems to be reasonably consistent with the data, that international differences in human capital investment help to explain some of the international differences in productivity, and that investment in human capital provides returns primarily to the investor.

RESEARCH AND DEVELOPMENT

RESEARCH AND DEVELOPMENT is another type of investment that, like human capital, has characteristics that attract special attention. From a conceptual point of view, one of the main problems is the difficulty faced by agents in attempting to assess the risk and return of an R&D project. It is often claimed that financial market participants who are increasingly focused on short-term 'bottom line' investments do not recognize the value of R&D investment. Somewhat surprisingly, however, most studies of the market's reaction to R&D expenditures by firms support the alternative hypothesis that the market does recognize the long-run benefits of R&D investment.[2] But it must be recognized that this evidence relates to firms that have access to capital markets. The difficulty faced by investors trying to evaluate R&D investments may result in a capital market deficiency where firms with good projects can find no financing.[3]

A related empirical issue deals with the returns to research and development. It has been noted, for example, that the return to R&D often takes the form of product quality and that it will only be recognized if the analysis includes a careful quality adjustment measure.

Another issue is the extent to which returns to R&D are captured by the investing firm as opposed to other firms in the same industry or the same country. It has been shown that spillovers from one firm to another are an important part of total returns to investment.

Stiroh concludes his survey by observing that the conventional wisdom at this time is that R&D investment does significantly help to explain cross-sectional differences in productivity. Rodriguez and Sargent draw slightly different results from their examination of the Canada-U.S. productivity gap. They note that there are significant differences in the R&D capital stocks of the two countries but they argue that, if these differences are to explain the productivity gap, they must operate through spillovers. Though constrained by a lack of recent data, they further note that for spillovers to explain much of the productivity gap, spillover returns must be about ten times the private returns to investment.

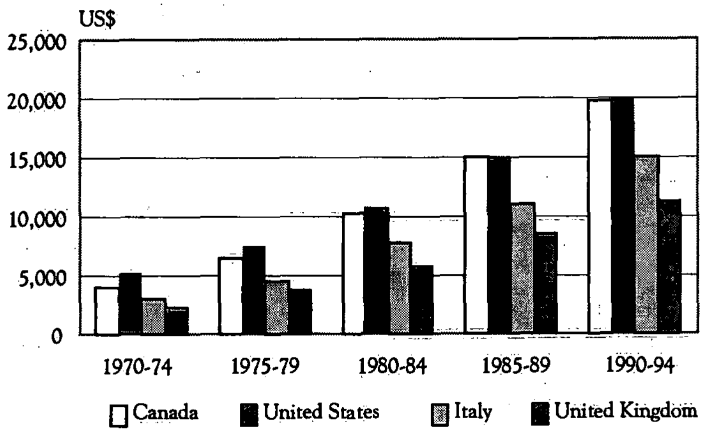
RELATIVE INVESTMENT AND PRODUCTIVITY IN CANADA

FIGURE 3 PRESENTS EVIDENCE from Kirova and Lipsey (1997), as reported in Stiroh, on broadly defined levels of capital per worker in Canada, the United States, the United Kingdom and Italy. Figure 4 shows the same figures but normalized by the level of investment in the United States, while Figure 5, based on Jorgenson and Yip (1999), depicts growth in investment per capita for the same countries. These figures indicate that quality-adjusted investment levels in Canada relative to other countries has not fallen dramatically.

Figure 6 reports labour productivity growth as a percentage of U.S. productivity for the same countries and here Canada's performance is relatively poor: its lag relative to the United States has actually increased slightly while other countries have closed the gap. Figure 7 illustrates labour productivity growth while Figure 8 illustrates total factor productivity growth. Both figures reflect the widely documented and discussed worldwide productivity slowdown that began in the mid 1970s. They also provide further evidence of a relative productivity slowdown in Canada as labour productivity growth and total factor productivity growth have both lagged almost all other countries in all years reported.

FIGURE 3

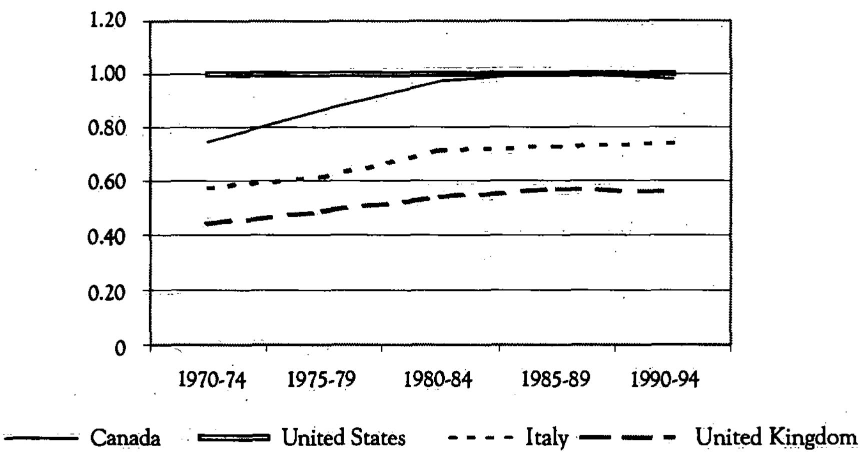
PER CAPITA CAPITAL FORMATION



Source: Kirova and Lipsey (1997), as reported in Stiroh (2000).

FIGURE 4

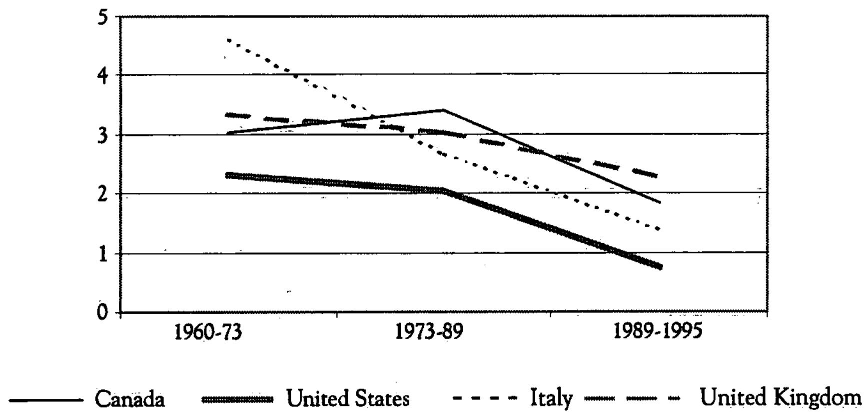
GROWTH IN PER CAPITA CAPITAL FORMATION



Source: Kirova and Lipsey (1997), as reported in Stiroh (2000).

FIGURE 5

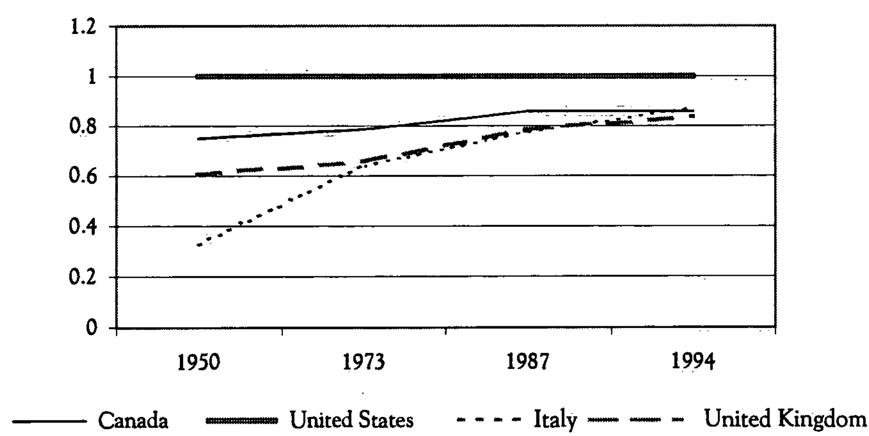
GROWTH IN PER CAPITA CAPITAL INPUT



Source: Jorgenson and Yip (1999).

FIGURE 6

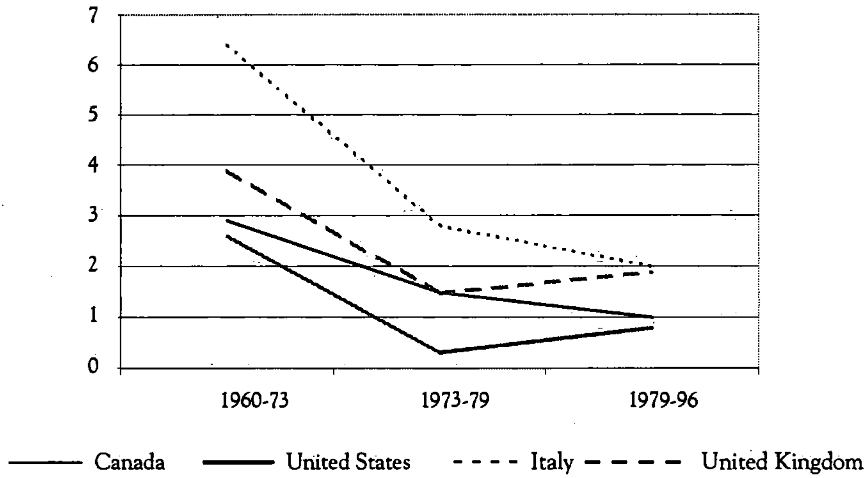
TRENDS IN LABOUR PRODUCTIVITY GROWTH RELATIVE TO THE UNITED STATES



Source: Van Ark (1996), as reported in Stiroh (2000).

FIGURE 7

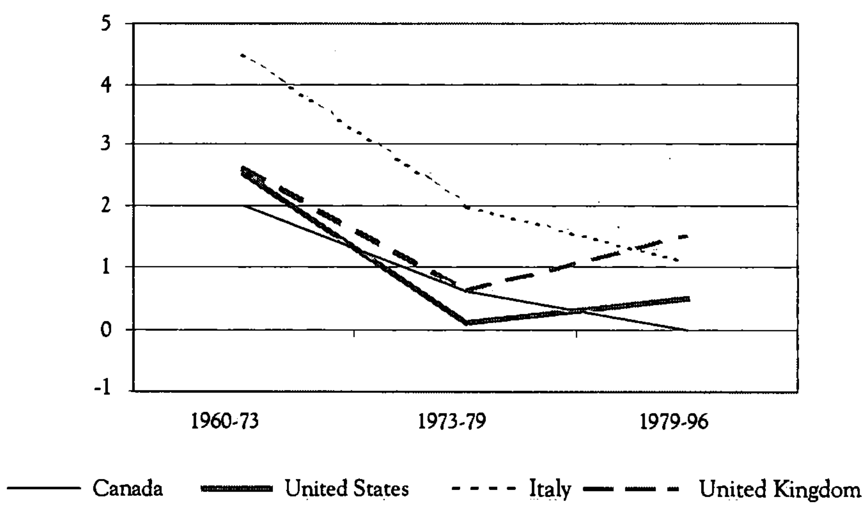
GROWTH IN LABOUR PRODUCTIVITY



Source: Sharpe (1999).

FIGURE 8

GROWTH IN TOTAL FACTOR PRODUCTIVITY



Source: Sharpe (1999).

In summary, investment is widely recognized as an important contributor to labour productivity yet its link to productivity in Canada is not clear. Per capita capital formation in Canada has not lagged that of other countries dramatically, yet productivity, both in terms of labour productivity and total factor productivity, has fallen relative to other countries.

THE SPECIAL ROLE OF EQUIPMENT INVESTMENT

INVESTMENT IN MACHINERY AND EQUIPMENT has been the subject of special attention for some time, but it is gaining more prominence of late. This interest is related to the fact that investment in equipment at one location or firm may enhance productivity elsewhere. This has the potential of providing a more complete explanation of total factor productivity and of identifying a role for government.

Long ago, Arrow (1962) suggested that the productivity of any factor of production may be an increasing function of the level of investment in the economy. The notion was that investment contributed to portable learning-by-doing. Recently, the work of DeLong and Summers (1991) has placed this issue in the spotlight and generated considerable debate. These authors find a strong statistical relationship between investment in machinery and equipment and economic growth. Based on data covering the 1960-85 period, they find that each percentage of GDP invested in machinery and equipment is associated with an annual increase of one third of a percentage point in subsequent GDP growth. They also estimate that the social return to equipment investment in a well-functioning market is in the order of 30 percent. To the extent that unpriced externalities exist, a case for government intervention can be made. Stiroh reviews recent research in this area and concludes that, while more research is needed, evidence presented so far " . . . suggests that investment in equipment primarily affects growth through the traditional, neoclassical channels. That is, investment leads to capital deepening and labour productivity, but not to total factor productivity."

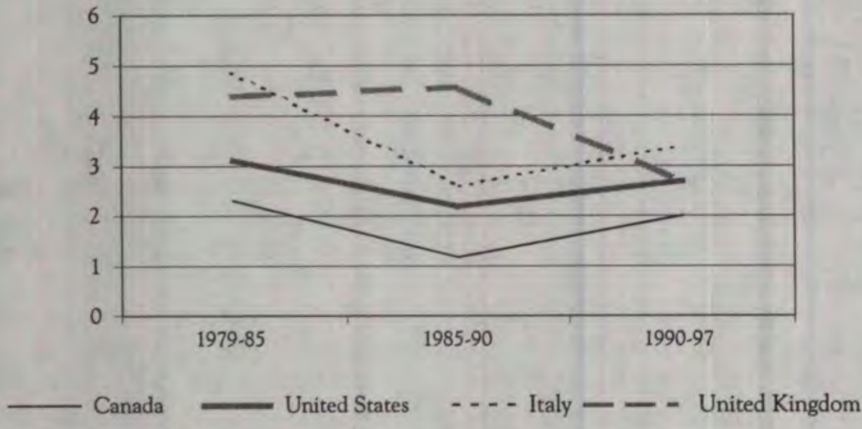
THE MANUFACTURING SECTOR

ALTHOUGH THE RELATIVELY POOR PRODUCTIVITY PERFORMANCE noted above is a cause for concern, there has been an even larger relative productivity slowdown in manufacturing. Figure 9 depicts data provided by Stiroh on relative labour productivity in manufacturing.

Figure 10 is based on a more recent study by Rao, Ahmad and Kaptein-Russell (2000) that examines Canada-U.S. productivity differences. It shows that the decline in productivity relative to the United States is worsening. The authors examine the role of investment in explaining productivity differences in the manufacturing sector and report a number of important findings.

FIGURE 9

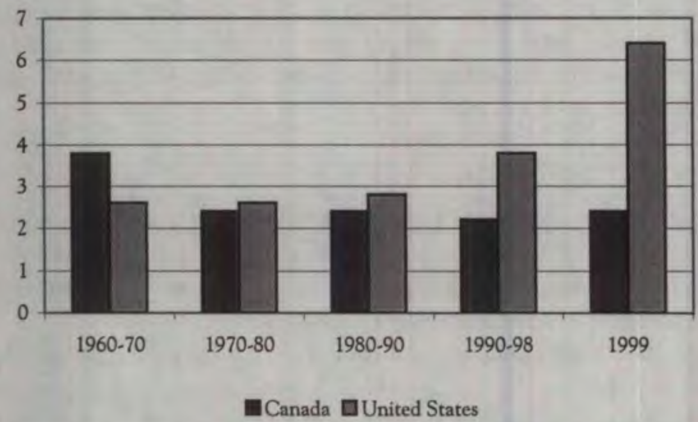
LABOUR PRODUCTIVITY IN MANUFACTURING



Source: Stiroh (2000).

FIGURE 10

CANADA-U.S. LABOUR PRODUCTIVITY IN MANUFACTURING, (AVERAGE ANNUAL PERCENTAGE LABOUR PRODUCTIVITY GROWTH)



Source: Rao, Ahmad and Kaptein-Russell (2000).

In terms of within-country results, they find that the differences in productivity levels across manufacturing sectors is highly correlated with machinery and equipment (M&E) and construction investment in both countries. Moreover, they find that labour productivity in both countries is also highly correlated with M&E investment intensity. In contrast, however, they find either little or no correlation between investment intensity and productivity growth.

They also study the productivity gap between Canada and the United States and find that it is positively correlated with the investment intensity gap between the two countries. They go on to consider the possibility that investment intensities differ because of different industrial structures but do not find supporting evidence.

CAPITAL MARKET IMPERFECTIONS

THE NEOCLASSICAL AND ENDOGENOUS GROWTH MODELS of the firm and of investment decisions reflect perfect-market assumptions. This approach is in sharp contrast to much of the corporate finance literature that examines imperfections due to taxes, transaction costs, incentive contracting problems and asymmetric information. Asymmetric information and adverse selection have been the focus of a rapidly-growing strand of the investment literature[4] identified with Fazzari, Hubbard and Petersen (1988). Somewhat surprisingly, it has received relatively little attention in the productivity literature.

The starting point of this work is the idea — first put in a finance context by Myers and Majluf (1984) — that firms may prefer not to invest in valuable projects if the market does not recognize their quality as well as their managers themselves do. That is, firms that need external financing to exercise investment options will trade-off the net present value of the investment against the 'dilution' resulting from the fact that they are undervalued by the market.

This simple idea can explain the widely documented fact that firms usually see the price of their existing shares fall when they announce plans to issue new equity. In the context of investment theory, this insight has two important implications, often referred to as the pecking-order hypothesis. First, firms prefer to use internal financing — in a sense, it costs less because it is not subject to informational problems. Second, firms prefer to finance themselves with secured loans if their assets have verifiable values, essentially for the same reason.

Researchers have tested these assertions by examining the extent to which investment decisions increase with internal cash flows and net worth, which are taken as proxies for collateralizable assets. Hubbard (1998) summarizes this literature and concludes that "For many firms in the economy, available evidence is consistent with: (1) a gap between the cost of external and internal financing; and (2) a positive relationship between the borrower's spending and net worth, holding constant underlying investment opportunities."

Stiroh's view is that while this literature is interesting, it focuses on explaining investment levels and does not provide insight into the investment/productivity link. Rodriguez and Sargent do not refer to this literature at all. In spite of this, it seems that a number of aspects could be developed.

For instance, our understanding of the productivity/investment link has improved considerably with the development of constant-quality indexes. These indexes do reflect the user cost of capital. Clearly, an effective measure of the cost of capital would account for the cost differences between internal and external funds.

In addition, the existence of capital market imperfections implies that investment will take place when a valuable opportunity arrives *and* the firm has sufficient internal financing or collateralizable assets in place. Since this is more likely to occur during busy segments of the business cycle, there is a cyclical element to investment and, thus, productivity. Related to this is the fact that investment in a cash-constrained firm is more likely to take place after a period of growth. Indeed, Blomstrom, Lipsey and Zejan (1996) find evidence to support the hypothesis that investment follows growth rather than the other way around.

The notion that capital market imperfections may be fundamental determinants of investment decisions has motivated a line of research that examines the relationship between capital market development and growth. This research, summarized by Carlin and Mayer (2000), finds a relationship between the development of the financial system and economic growth. The development of financial markets tends to relax the constraints on industries that require considerable external financing, thereby generating economic growth. Carlin and Mayer extend this reasoning by looking specifically at how capital formation and R&D interact with country and industry characteristics. They find strong links between market systems, the advent of accounting disclosure and legal protection of shareholders, and the growth of equity-financed and skill-intensive industries.

Conclusions and Research Agenda

THE TWO PAPERS THAT FOLLOW in this part of the book provide an excellent review of our understanding of the link between investment and productivity from both the neoclassical and the endogenous growth perspectives.

In some respects, they paint a fairly consistent picture of the role of investment in productivity. Investment, defined to include a broad set of diverse categories, is a crucial factor in explaining productivity. Investment in human capital, though different from a contracting perspective, also plays a critical role in explaining productivity growth. Both also find that R&D expenditures are important in explaining productivity.

These papers also recognize that investment levels in Canada relative to the United States and other industrialized countries have not been particularly low in aggregate. They also agree on the fact that there has been relatively low investment in machinery and equipment and R&D. It is not clear, however, that these differences in growth rates can explain the differences in productivity growth between the two countries.

Both papers are primarily concerned with comparing the neoclassical and the endogenous growth models. Clearly, these have been the work horses of the profession to date, and they have provided us with important and fascinating insights.

An alternative approach that has so far captured less attention comes from the corporate finance literature. At the heart of the study of corporate finance is the investment decision made by the individual corporate manager. This area of study is relatively uninteresting in a perfect-market setting and research in corporate finance has accordingly focused on how the investment decision is made in the context of numerous market imperfections. Perhaps the strongest finding from this work is that informational problems are central to the firm's investment decision. This micro-economic notion has prompted considerable research into the connection between investment decisions and such factors as internally generated capital and the development of the legal and accounting systems.

The contrast between the traditional macro-economic approach to investment and the corporate finance approach can be dramatic. For example, the user cost of capital is taken to be the 'interest rate' prevailing at a point in time. However, in the presence of informational problems the return that investors think they are demanding can be substantially lower than the rate that managers think they are paying. In this context, how does one define the user cost of capital?

The main research and policy conclusion that derives from this review is that much more needs to be done in order to understand how informational imperfections affect aggregate investment and productivity.

ENDNOTES

1 Jorgenson and Yip (1999).
2 Evidence on R&D investment and market values is reviewed in Giammarino (1995).
3 The impact of asymmetric information on the investment process is discussed in greater detail below.
4 See Hubbard (1998) for a recent survey of this literature.

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13

Investment and Productivity Growth: A Survey from the Neoclassical and New Growth Perspectives

Summary

THIS CHAPTER REVIEWS THE LARGE LITERATURE on investment and productivity with the debate between neoclassical and new growth theories providing a context for discussion. Both schools of thought regard investment, broadly defined to include purchases of tangible assets, human capital expenditures, research and development efforts, etc., as the fundamental source of improved productivity and economic growth, but the two views diverge on the exact transmission mechanism. Most importantly, the neoclassical framework focuses on diminishing returns to capital that are primarily internal to investors, while new growth models emphasize increasing returns and possible external effects as productivity gains spill over to others. This crucial dichotomy leads to differences regarding the role of investment as a source of growth, policy prescriptions, and implications for long-run gains in productivity and living standards. The paper then reviews several empirical and conceptual issues relating to investment and productivity and outlines areas for future research.

Introduction

ECONOMISTS HAVE LONG RECOGNIZED that investment is a crucial source of productivity and economic growth. By providing workers with more capital and improving labour productivity, investment expands output and raises living standards. The fundamental importance of this linkage has spawned an enormous amount of research — both theoretical and empirical — focused on the relationship between investment, productivity, and economic growth.

The purpose of this paper is to provide a broad survey of the recent literature that relates investment to productivity, a link that depends critically on an understanding of the process of economic growth. The pioneering work of Ramsey, Domar, Harrod, Solow and others first laid a framework centered on private investment in tangible assets and the resulting accumulation of physical capital in a neoclassical framework. Recent contributors have used this neoclassical model as a starting point, but extended the analysis in ways that have irrevocably altered our perspective on the importance of investment as a source of productivity.

One important innovation was the expansion of the investment and capital concepts by Becker, Denison, Griliches, Jorgenson, Mincer, Schultz, and others beyond private investment in tangible assets to include investment-driven substitution between heterogeneous assets, human capital accumulation, research and development expenditures, and investment in public infrastructure. While emphasizing a broader view of investment, this literature has typically remained in the neoclassical tradition with diminishing returns to broadly-defined capital and benefits from investment that primarily accrue internally in the form of enhanced productivity or higher wages. This focus on diminishing returns to capital yields the standard, neoclassical conclusion that long-run growth in per capita variables is driven by exogenous, and entirely unexplained, technological progress.

A second major innovation moved away from the neoclassical framework to examine alternative productivity channels in the "new growth" theory of Arrow, Grossman, Helpman, Lucas, Romer and others. This view attempts to explain long-run growth internally by either removing the diminishing returns assumption about capital or by modeling technological progress as the result of choices made by optimizing agents. This view also attaches greater significance to certain types of investment that possibly produce externalities, which can generate non-diminishing returns and yield an additional productivity boost through production spillovers or the associated diffusion of technology.

The first part of this paper sketches the role of investment in determining productivity within these two frameworks. While both are useful and contribute to our understanding of productivity growth, the empirical evidence suggests that the traditional neoclassical focus on input accumulation and internal returns explains much of the improvements in labour productivity. For example, the strong performance of the newly industrialized Asian economies is primarily due to their rapid accumulation of physical and human capital, with a relatively small role for technological progress. Likewise, massive substitution towards high-tech capital goods is raising the relative productivity of U.S. firms and industries that are able to invest and restructure their activities with little evidence that productivity gains spill over to others.

Investment and input accumulation are not the whole story, however, with roughly one-fifth of U.S. post-war growth remaining unexplained in a neoclassical analysis. This leaves an obvious need for an explanation of the forces driving technological progress. The new growth theory can fill this gap. Thus, these two frameworks can be viewed as complements rather than substitutes. Neoclassical methods account for the many types of input accumulation that explain the majority of growth, and thus yield a more accurate estimate of the rate of technological progress. The new growth theory then provides a conceptual foundation for technological progress falling outside of the neoclassical framework.

The second part of the paper reviews a wide range of current issues relating to investment and productivity. These include international evidence on investment spillovers from equipment investment, potential research and development spillovers, the "computer productivity paradox," the impact of investment on labour market outcomes, the renewed embodiment controversy, and recent micro-economic evidence from large longitudinal databases. By outlining some of the important policy implications of the current research and summarizing relevant questions that remain unanswered, this section highlights specific areas for future research on the relationship between investment and productivity.

The paper is organized as follows. The section entitled *Investment, Productivity and Growth* briefly outlines the traditional role played by investment in the neoclassical model of growth, including broader concepts of investment and capital, and then contrasts models of endogenous growth. The following section, entitled *Current Issues and Results*, looks at current issues relating to investment and productivity. The last section concludes the paper and discusses topics that would be suitable for future research.

INVESTMENT, PRODUCTIVITY AND GROWTH

ECONOMIC GROWTH THEORY has recently enjoyed a revival, with insights from both classic and recent contributions providing an appropriate point of departure for a discussion of investment and productivity. The growth literature has recently bifurcated, however, with arguments made for both a neoclassical model of growth and an alternative, new growth approach.[1] Although investment plays a central role in both, conceptual differences lead to contrasting views of the investment-productivity nexus.

Economists often think of investment as the purchase of tangible assets that contribute to current and future production as capital is accumulated. Indeed, this concept was featured in the early analysis of Cobb and Douglas (1928), Tinbergen (1942), Solow (1956, 1957) and others that first used an "aggregate production function" to describe the relationship between an economy's output and primary inputs, e.g. tangible capital and labour. This perspective has changed, however, with Mankiw (1995) concluding: "...there is an increasing consensus that the role of capital in economic growth should be more broadly interpreted" (p. 308). If capital is interpreted more broadly, then investment must also be defined more broadly so as to include the purchase of any asset or service that generates future production returns. Jorgenson (1996) summarizes this view with a concise definition:

> Investment is the commitment of current resources in the expectation of future returns and can take a multiplicity of forms...the distinctive feature of investment as a source of economic growth is that the returns can be internalized by the investor. (p. 57)

This broader definition includes investment in tangible assets, as well as education, training, other human capital accumulation, or research and development, since these actions are specifically undertaken by the firm or worker to increase their own future benefits, which ultimately contribute to output, productivity and growth. As a preview of the subsequent discussion, the idea that investment, broadly defined, primarily generates internal and diminishing returns is a hallmark of the neoclassical model of investment, productivity and growth that differentiates it from the new growth theory.

The Neoclassical Model

THE STANDARD NEOCLASSICAL GROWTH MODEL is familiar and will be reviewed only briefly here. The seminal papers of Solow (1956, 1957) formalized the neoclassical model, integrated the aggregate production function with national income data, and formed the basis for much of the applied growth analysis. In this framework, the role of investment can be summarized by two familiar equations.

The relationship between output, Y, and capital input, K, labour input, L, and "Harrod-neutral" technology, A, can be described with an aggregate production function:

$$(1) \quad Y = f(K, A \cdot L),$$

and the capital accumulation equation, which governs the relationship between investment in tangible assets, I, and the capital stock, S, is the well-known perpetual inventory relationship:

$$(2) \quad S_t = (1 - \delta) \cdot S_{t-1} + I_t,$$

where δ is depreciation, and I_t can either be determined endogenously by profit-maximizing firms or assumed to be some fixed proportion of output, say sY_t.

Note that the production function includes a measure of capital input, K, while the perpetual inventory equation defines the capital stock, S. These two concepts are closely linked and discussed below.

Under the neoclassical assumptions of competitive factor markets and constant returns to scale where all inputs are paid their marginal products, one can derive a standard growth accounting equation, as in Solow (1957). That is, if technology is Hicks-neutral, $Y = A \cdot f(K, L)$, then output growth equals the share-weighted growth rates of primary inputs plus total factor productivity growth, i.e. the famous "Solow residual," $\Delta \ln A$, as in:

(3) $\Delta \ln Y = v_K \Delta \ln K + v_L \Delta \ln L + \Delta \ln A,$

where v_K is capital's share of national income, v_L is labour's share of national income, and the neoclassical assumptions imply that $v_K + v_L = 1$. Note that the Solow residual is implicitly defined by Equation (3) and measures the true rate of technical change only under certain neoclassical conditions.

Equations (2) and (3) show the link between investment in tangible assets and economic growth as the accumulation of capital stock contributes to growth in capital input, which in turn contributes to output growth in proportion to capital's share of national income. One can then derive the neoclassical relationship between investment and labour productivity growth, defined as output per hour worked, by transforming Equation (3) as:

(4) $\Delta \ln y = v_K \Delta \ln k + v_L (\Delta \ln L - \Delta \ln H) + \Delta \ln A,$

where lower-case letters express values per hour worked. Growth in average labour productivity (ALP), given by $\Delta \ln y$, depends directly on the rate of per hour capital accumulation (capital deepening), $\Delta \ln k$, growth in labour quality, measured as the difference between the growth of labour input and the growth of hours worked, $(\Delta \ln L - \Delta \ln H)$, and the growth in total factor productivity (TFP), $\Delta \ln A$.[2]

The striking implication of the neoclassical model is that, in the long run, per capita variables will not grow unless there is exogenous technical progress. This reflects the standard neoclassical assumptions of constant returns to capital and labour, and diminishing returns to capital alone. Moreover, this conclusion is independent of any changes in policy variables like the savings rate. In this sense, the neoclassical model is not a growth model. Nonetheless, the neoclassical model has been a useful tool for measuring and quantifying the proximate factors that determine productivity growth.

The appealing simplicity and intuition of this neoclassical framework has made it the backbone of applied and theoretical work on productivity and economic growth.[3] Despite its popularity, however, the neoclassical model leads to several troubling results. First, TFP growth is entirely exogenous to the model and, as mentioned above, there is no steady-state growth in per capita income without exogenous technological progress. Moreover, despite being totally unexplained, early empirical research found TFP growth to be the dominant source of per capita income and labour productivity growth. Indeed, Solow (1957) originally attributed nearly 90 percent of U.S. per capita output growth to exogenous technical progress, leaving many economists unsatisfied. In addition, the neoclassical model did not offer a compelling explanation for the U.S. productivity slowdown in the 1970s. Finally, the international data did not seem to fit with the basic neoclassical model in terms of capital shares and convergence properties.[4]

These shortcomings set the stage for several lines of subsequent research on the relationship between investment and productivity growth. One school of thought, originated by Jorgenson and Griliches (1967) and summarized in Jorgenson (1990, 1996), remained firmly embedded in the neoclassical tradition and sought to develop better measures of investment, capital, labour, and other omitted inputs in order to reduce the importance of the unexplained residual. A second school moved beyond the neoclassical model and sought to provide an endogenous mechanism for the evolution of technical progress, which was left unexplained in earlier work. By explicitly modeling the dynamics of competition, innovation, and production spillovers, this research culminated in models of endogenous growth in the new growth theory.

EXPANDING THE INVESTMENT CONCEPT

THE NEOCLASSICAL MODEL DESCRIBED ABOVE can easily be extended beyond investment in tangible assets to account for any accumulated input that contributes to production. This includes investment-driven substitution between heterogeneous tangible assets, investment in human capital through education and worker training, research and development efforts, or public infrastructure expenditure. Note that an important goal of this research is to better measure the underlying rate of technological progress by effectively removing the impact of measurable inputs; simply adding additional inputs does not yield endogenous growth as long as the neoclassical assumption about diminishing returns to broadly-defined capital holds.

Heterogeneous Tangible Assets

In the context of Equation (1), K measures the service flow of capital inputs, which encompasses the services from many heterogeneous assets, ranging from long-lived structures to short-lived equipment. By recognizing that tangible assets have different acquisition prices, service lives, depreciation rates, tax treatments, and ultimately marginal products, Jorgenson and Griliches (1967) formally incorporated heterogeneity of inputs by creating constant-quality indices for capital and labour inputs. In contrast, Solow (1957) originally used a simpler measure of aggregate capital stock, as in Equation (2).[5]

A constant quality index of capital input is estimated using an asset-specific "user cost of capital" to aggregate heterogeneous capital stocks, rather than acquisition prices. By weighting assets by their user cost, which equals the marginal product in equilibrium, the index of capital input incorporates important differences in the productive contribution of heterogeneous assets as the composition of investment and capital changes. It should be emphasized that "quality" changes in this framework represent changes in the composition of assets and not higher productivity from any particular asset. Quality change of that type, e.g. the improved performance of more recent computers, is handled by the investment deflator and is discussed below in the section on the computer productivity paradox.

As derived in Hall and Jorgenson (1967) and elaborated in Jorgenson and Yun (1991), the user cost of capital, $P_{k,t}$, measures the annualized cost of using a piece of capital for one period, from $t-1$ to t, which reflects the opportunity cost of purchasing the asset plus the depreciation of the asset less any capital gains, all adjusted for tax considerations. The user cost is estimated with a capital services price equation:

$$(5) \quad P_{k,t} = \frac{1 - ITC - Z \cdot \tau}{1 - \tau} \cdot (i_t \cdot P_{a,t-1} + \delta \cdot P_{a,t} - \pi_t \cdot P_{a,t-1}),$$

where ITC is the investment tax credit, Z is the present discounted value of capital consumption allowances, $P_{a,t}$ is the acquisition price of capital or investment, δ is the rate of geometric depreciation, and π_t is the revaluation rate of the asset price, all for each individual asset; i is the nominal rate of return and τ is the statutory tax rate that apply to all assets.

As firms respond to changes in relative prices, for example by moving towards high-tech assets with relatively high marginal products, the aggregate capital input (or capital services flow) grows faster than the aggregate capital stock. This reflects the substitution between heterogeneous assets. Thus, to correctly estimate the contribution of capital to growth and isolate the rate of technological progress, one must utilize a capital services concept that incorporates substitution between heterogeneous assets.

Jorgenson and Stiroh (1999, 2000) apply this capital services methodology to the U.S. economy and conclude that investment in tangible assets was the dominant source of growth during the post-war period. These results, reported in Table 1 and taken from Jorgenson and Stiroh (2000), show that output grew

TABLE 1

THE SOURCES OF U.S. ECONOMIC GROWTH AND THE ROLE OF INFORMATION TECHNOLOGY, 1959-98

	1959-98	1959-73	1973-90	1990-98
Output Growth	3.63	4.33	3.13	3.49
Contribution of Capital Inputs (K)	1.26	1.44	1.16	1.17
Non-IT (K_n)	0.94	1.26	0.81	0.64
Information Technology (K_{IT})	0.32	0.18	0.35	0.53
Contribution of Consumers' Durables Services (D)	0.51	0.63	0.47	0.39
Other than Computers and Software (D_n)	0.47	0.63	0.44	0.27
Computers and Software (D_c)	0.04	0.00	0.02	0.13
Contribution of Labour Inputs (L)	1.23	1.25	1.17	1.33
Aggregate Total Factor Productivity	0.63	1.01	0.34	0.59

Notes: Contributions of inputs are real growth rates weighted by average, nominal shares. All values are average, annual percentages.
Source: Jorgenson and Stiroh, 2000, Table 2.

3.6 percent annually from 1959 to 1998, with capital inputs, including consumers' durable assets, accounting for 49 percent of total growth, while labour inputs accounted for 34 percent, and the TFP residual the remaining 17 percent. Gordon (1999) presents a longer historical perspective, dating back to 1870, where he compares alternative input measures for the U.S. economy; he concludes that quality adjustment of labour and capital inputs were important sources of long-run growth. By measuring all productive inputs, one is better able to gauge the relative importance of technological progress.

However, these types of growth accounting exercises must be kept in a proper perspective. As pointed out by Hulten (1979), this methodology depends critically on the neoclassical assumptions made to measure the Solow residual. In addition, growth accounting tends to understate the importance of technological change since part of capital accumulation is itself induced by faster technical progress. It must be stressed, however, that the goal of growth accounting is to correctly measure observable inputs so that technological progress can be isolated and measured more accurately.

Human Capital

Economists have recognized the importance of investment in human beings at least since the early work of Mincer (1958, 1974), Schultz (1961) and Becker (1962).[6] Expenditures on education, job-training, labour migration, and health care are all increasing the quality of human labour and enhancing productivity, and are rightly called investments. As early as 1961, the similarities between investments in tangible capital and in human capital, e.g. tax incentives, depreciation, pricing imperfections and the primarily internal benefits of human capital investment, were discussed by Schultz (1961, pp. 13-15).

Griliches (1960), Denison (1962) and Jorgenson and Griliches (1967) formally incorporated heterogeneous labour inputs into an aggregate growth analysis by weighting labour hours with relative wages to account for differences in human capital and productivity. Similar to the measurement of capital, this approach incorporates substitution between different types of labour and results in a constant quality index of the labour input that is suitable for the production function analysis of Equation (1). (See Ho and Jorgenson, 1999, for details.) The accumulation of human capital is an important source of growth and is now routinely included in growth analyses. For example, the U.S. Bureau of Labor Statistics (BLS, 2000a) reports that one-fifth of U.S. non-farm labour productivity growth from 1990 to 1997 was due to changes in the composition of labour, i.e. improved labour quality.

In an important paper in support of the broad neoclassical model, Mankiw, Romer and Weil (1992) formally include investment in human capital in an augmented Solow growth model. Employing a Cobb-Douglas specification for aggregate output, they explicitly model human capital as a determinant of output:

$$(6) \quad Y = K^{\alpha}H^{\beta}(AL)^{1-\alpha-\beta},$$

where H is the stock of human capital and A is labour-augmenting technical change.

Mankiw, Romer and Weil (1992) use a measure of education attainment to approximate human capital accumulation and find that the model fits the data well in terms of growth convergence predictions and estimated output elasticities. They conclude that the augmented Solow model is consistent with the international evidence.[7] More recently, Hall and Jones (1999) use a similar model to compare levels of output across a wide range of countries and find that human capital differences explain some, but certainly not all, of the wide variation observed in per capita output levels.

Taking a micro-economic perspective, Black and Lynch (1996) find that human capital is an important determinant of cross-sectional differences in establishment productivity, e.g. a 10 percent increase in average education leads to an 8.5 percent increase in manufacturing productivity and to a 12.7 percent increase in non-manufacturing productivity. Again, this research supports the neoclassical view: investment in human capital leads to internal benefits for the economic agent making the investment.

Research and Development

A second type of investment that can be incorporated into the neoclassical model is investment in research and development (R&D), defined broadly as expenditures on new knowledge that improves the production process. The growth impact of R&D has received considerable attention, particularly within the context of spillovers, but the primary impact of R&D investment is internal (Griliches, 1973, 1979). Aghion and Howitt (1992), who are important contributors to the new growth theory, recognize this by noting that "technological knowledge is itself a kind of capital good...and it can be accumulated through R&D" (p. 26). Since firms presumably undertake R&D investment to improve their own production process and raise profits, many endogenous growth models explicitly treat spillover effects as secondary, unintended consequences that create non-diminishing returns to broadly-defined capital. This distinction between internal/external benefits and diminishing/non-diminishing returns delineates the role of R&D in the neoclassical and the new growth theories.

While it is conceptually straightforward to treat R&D as a neoclassical factor of production, large practical difficulties prevent the contribution of R&D from being easily estimated. Griliches (1995), Hall (1996) and Jorgenson (1996) all emphasize the difficulty of measuring the contribution of R&D to growth because of thorny measurement problems and a lack of adequate data. Hall (1996) points out that R&D is often associated with product improvements, and the measured impact of R&D therefore depends critically on how price deflators are constructed and how output is deflated. As a concrete example, Griliches (1994) shows that the inclusion of the U.S. computer industry, which has a quality-adjusted price deflator, in a cross-sectional analysis has an enormous impact on the estimated gross rate of return to R&D. In addition, one must estimate an appropriate depreciation rate to calculate the productive stock of R&D capital.

Despite these problems, many studies have tried to measure the impact of R&D.[8] Griliches (1995) presents a "skeletal model" of R&D that is a straightforward extension of Equation (1):

$$(7)\quad \ln Y = \alpha(t) + \beta \ln X + \gamma \ln R + u,$$

where X is a vector of standard inputs, e.g. capital and labour, and R is a measure of cumulative research efforts. Alternatively, Equation (7) can be rewritten in terms of growth rates.

A consensus has emerged that R&D capital contributes significantly to cross-sectional variation in productivity — Hall (1996) reports an elasticity of 0.10 to 0.15 using data through 1977, while Griliches (1995) finds that the estimated elasticity of output with respect to R&D capital typically lies between

0.06 and 0.10. It is important to note, however, that Equation (7) examines the relationship between firm or industry productivity and its *own* R&D stock; thus, R&D is treated as a conventional neoclassical input. The impact of R&D spillovers is addressed below.

Public Infrastructure

The neoclassical view described above focuses on private investment by optimizing firms and individuals as the primary source of growth. However, in a series of influential and controversial papers, Aschauer (1989a,b, 1990) argued that core infrastructure is an important source of productivity growth. In the canonical specification, Aschauer (1989a) includes a flow of productive services from government capital, G, into the neoclassical model:

$$(8) \quad Y = A \cdot f(K, L, G),$$

and concludes that there is "an important role for the net public capital stock in the 'productivity slowdown'." (p. 177)

These claims led to a wide-ranging debate that addressed the policy implications and pointed out important econometric issues, including potential biases from common trends, omitted variables, and potential reverse causality.[9] Even if one ignores the econometric and methodological criticism, it does not necessarily mean that economy-wide productivity and growth can be easily improved through public investment.

For example, Aschauer (1989b) raises the issue of crowding out of private investment by public investment, while Nazmi and Ramirez (1997) find empirically strong crowding out effects for Mexico. Morrison and Schwartz (1996) find a significant productivity impact of infrastructure across U.S. states, but they also report evidence suggesting that, after accounting for the social cost of infrastructure investment, the net return may be close to zero. Vijverberg, Vijverberg and Gamble (1997) compare three alternative econometric approaches — a production function, a cost function, and a profit function — that all are based on an augmented production function similar to Equation (8) and report tremendous variation in results across models and specifications. They draw no firm conclusions about the impact of public investment on private productivity. Nadiri and Mamuneas (1994) find that highway investment contributes to productivity and output growth at both the sectoral and aggregate levels in the United States, although output elasticity for private capital is four times as large as that of highway capital in all industries. Finally, Fernald (1999) shows that investment in roads contributed to productivity before 1973, but suggests that new investment in roads would likely have a normal or even zero rate of return.

In an international comparison, Hulten (1996) utilizes a similar framework to examine the productivity impact of both the quantity and quality of public investment in 42 countries from 1970 to 1990. Cross-sectional regressions that control for private tangible and human capital suggest that "infrastructure effectiveness" has an impact on growth more than seven times larger than the impact of public investment. Sanchez-Robles (1998) also focuses on alternative measures of public infrastructure, i.e. an index of "physical units of infrastructure," and finds a significant correlation with output growth. This suggests that there is no simple way to gauge the impact of infrastructure investment.

One obvious difference between private and public investments concerns their financing mechanisms. As emphasized above, private investment provides returns to private agents that can be internalized, and thus there is no place for government intervention. The argument for state-financed infrastructure, however, is a traditional public-good argument whereby returns cannot be fully recouped by a private investor, which can lead to underprovision of the good. Gramlich (1990) examines various types of infrastructure investments and explores the rationale for their public provision.

Caveats about the Neoclassical Approach

The common theme in all of the preceding studies is that investment — broadly defined as the sacrifice of present consumption for future consumption — is the key determinant of both long-run productivity growth and cross-sectional variation in productivity. Moreover, the defining feature that places them squarely in the neoclassical tradition is that aggregate capital, however defined, exhibits diminishing returns so that long-run per capita growth depends on exogenous technical progress. The new growth theory, discussed next, offers an alternative view.

As an important caveat, however, one must recognize that many of these studies examine only a subset of investment variables and there is only so much variation in productivity to explain. For example, the well-known productivity slowdown has been attributed by various authors to a shortfall of public infrastructure investment, a shortfall of R&D investment and a shortfall of equipment investment, but all cannot be responsible for the entire slowdown.[10] Only by accounting for the quantity and quality of all types of production inputs can one correctly estimate the marginal importance of each type of investment and fully understand their link with productivity growth.

The New Growth Theory

AN IMPORTANT MOTIVATION for the endogenous growth literature was the desire to avoid the neoclassical implication that diminishing returns to capital make exogenous technical progress the only source of long-run growth in per capita variables. Endogenous growth models tried to explain how private economic agents make decisions that determine long-run growth through the dynamics of competition and innovation, production spillovers, increasing returns, and other non-traditional effects.[11] This literature is quite varied and Aghion and Howitt (1998) provide a detailed summary of the various components of endogenous growth theory.

The early work on endogenous growth begins with Arrow (1962), Shell (1966) and others, and has been revisited in important papers by Romer (1986, 1990), Lucas (1988) and Grossman and Helpman (1991). A common theme of these papers is an economic explanation of why broadly-defined capital may not suffer from diminishing returns. In contrast, the standard neoclassical model typically assumes constant returns to all inputs, and thus diminishing returns to capital alone.

As one example, firms may face constant returns to scale on private inputs (and, therefore, diminishing returns to accumulated inputs), but the economy-wide level of technology may depend on the aggregate stock of some privately provided input.[12] Arrow (1962) emphasizes "learning-by-doing," where investment in tangible assets generates spillovers as aggregate capital increases. He uses past gross investment to index experience and his learning-by-doing model can be written in simplified form as:[13]

$$(9)\quad Y_i = A(K) \cdot f(K_i, L_i),$$

where an i subscript represents firm-specific variables and K is aggregate capital.

Romer (1986) essentially made $A(.)$ a function of the stock of R&D, while Lucas (1988) modelled $A(.)$ as dependent on the stock of human capital, and Coe and Helpman (1995) argued that $A(.)$ also depends on the R&D stock of international trading partners. Barro (1990) presented an alternative specification of endogenous growth in a model with constant returns to scale on private capital and government services, but diminishing returns on private capital alone.

This type of investment spillover, whether from tangible capital, human capital or R&D expenditures, is the fundamental distinction between the neoclassical model and this strand of the new growth theory. Simply including additional inputs, e.g. public infrastructure or human capital, is not enough to generate endogenous growth if these other assets are accumulated like traditional tangible assets, if all returns are internalized, and if there are diminishing returns to aggregate capital. Lucas (1988), for example, explicitly states: "I want to consider an external effect. Specifically, let the average level of skill or human capital...also contribute to the productivity of all factors" (p. 18), while Romer (1986) emphasizes that "investment in knowledge suggests a natural externality. The creation of new knowledge by one firm is assumed to have a positive external effect on the production possibilities of other firms because knowledge cannot be perfectly patented or kept secret" (p. 1003). Coe and Helpman (1995) state that "when a country has free access to all inputs available in the world economy, its productivity depends on the world's R&D experience" (p. 862). This has a natural interpretation as a production spillover, since gains do not depend on own-resource expenditure, and provides the key distinction from the neoclassical model.

When commenting on Jorgenson (1996) and describing the neoclassical framework, Basu (1996) concludes:

> In his (Jorgenson's) framework, "technology" is just knowledge (a shorthand for R&D) and other forms of human capital. On the other hand, the New Growth theory, which also treats knowledge as a form of capital, believes that knowledge is special, in the sense that investors cannot fully internalize the benefits from accumulating knowledge. The New Growth theory thus has large spillovers to knowledge accumulation. (p. 79)

The existence of spillovers is a significant empirical question that has generated a vast literature for obvious reasons. If investment of any type — tangible assets, human capital, or R&D — generates benefits for the economy that cannot be internalized by private agents, then this suggests different growth paths and policy implications. Since investment may be too low from society's point of view, spillovers open a role for government intervention. The empirical evidence on spillovers from different types of investment is reviewed in the following section.

A class of models that deserves special mention in a discussion of investment and productivity relates to "general purpose technologies" (GPTs). Formalized by Bresnahan and Trajtenberg (1995), this line of research characterizes GPT innovations "by their potential for pervasive use in a wide range of sectors and by their technological dynamism" (p. 84). They argue that investing in and adopting GPT innovations like the steam engine, electricity and semi-conductors bring productivity gains to a wide range of industries and applications. Helpman (1998) offers a review and a collection of recent papers.

GPTs fall into the class of endogenous growth models because they explicitly include two types of investment-related spillovers. First, there are "innovational complementarities," which raise the productivity of R&D in sectors that use a GPT. For example, the computer chip may allow a financial service firm to innovate in more profitable and productive ways. Second, there are horizontal externalities when many sectors reap the benefits of a GPT, but coordination problems lead to underprovision of the GPT. These externalities can lead the market to provide a sub-optimal amount of the GPT. By exploring how a certain innovation diffuses through the economy, this type of research provides an important theoretical framework for the empirical search of production spillovers. This interesting explanation for a well-known phenomenon like the computer revolution deserves continued attention and further research.

As a final point to improve clarity, it should be noted that the term "endogenous" is used by both neoclassical and new growth advocates, but their interpretations are subtly different. Jorgenson (1996) and Jorgenson and Yip (1999), for example, use the word "endogenous" to refer to all growth that can be attributed to the accumulation of measurable inputs, i.e. all growth except the unexplained Solow residual. New growth theorists, on the other hand, use "endogenous" when explaining the evolution of the residual. That is, the neoclassical economists have developed sophisticated measurement tools to reduce the magnitude of the exogenous residual, while the new growth theorists have developed sophisticated growth models to explain the residual as a result of specific actions of economic agents.

Although both views are attempting to explain growth, they are focusing on different aspects, which has led to some confusion in the debate. More importantly, the two explanations need not be mutually exclusive since even a neoclassical-style analysis of the U.S. economy leaves a large role for the unexplained residual. Thus, there are important explanatory roles for both. The neoclassical and the new growth views can be combined by using neoclassical explanations to focus on correctly measuring broadly-defined capital accumulation, conditional on the level of technology, while new growth explanations can provide insights into the evolution of technology and the sources of the residual.

CURRENT ISSUES AND RESULTS

THIS SECTION REVIEWS SEVERAL AREAS of the current research relating to investment, productivity and growth. While significant advances have been made in all these areas, many unanswered questions remain and there is ample room for future research.

INTERNATIONAL COMPARISONS

DESPITE LARGE PRACTICAL AND CONCEPTUAL DIFFICULTIES, many authors have examined international differences in investment and productivity. van Ark (1996) provides a survey of methodologies, describes many of the difficulties involved in comparing productivity across countries, e.g. conversion to a common currency, capital stock and quality differences, variation in the productivity impact of education, etc., and reviews available international data sets. In this section, we briefly examine several recent empirical studies that provide estimates of investment and productivity performance across countries and sectors. However, we do not examine in any detail the large literature on cross-sectional growth regressions.

As a first step, it is useful to compare relative investment trends. Kirova and Lipsey (1997, 1998) provide estimates of various measures of capital formation for 13 countries (Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Sweden, the United Kingdom and the United States) and conclude that nominal values of traditional investment in tangible assets give a misleading perspective on capital accumulation. Consistent with the broader interpretation of capital described above, they calculate a broadly-defined version of investment by including consumer durables, education, research and development, and military capital formation. As shown in Table 2, Kirova and Lipsey (1997) report that, after taking into account price differences, the United States led with \$20,061 in broadly-defined real capital formation per worker from 1990 to 1994, followed by Canada with \$19,670, Belgium with \$17,447 and Japan with \$16,723. Billings (1996) focuses on tangible capital, concludes that the United States is lagging in terms of commercial structures, and points to differences in capital cost recovery methods as an explanation for the observed variation.

In terms of productivity comparisons, van Ark (1996) provides recent estimates of both relative labour productivity levels and growth rates for OECD countries. Results from that study are reported in Table 3 and exhibit several familiar trends — a sustained productivity slowdown after 1973 across most industrialized countries, increasing variation in productivity growth since 1987, and a relative productivity advantage through 1987 for the United States. However, France recently (1994) overtook the United States in terms of economy-wide labour productivity levels (real GDP per worker).

Building on the same underlying data, Pilat (1996) examines differences in productivity levels and growth rates across manufacturing and service industries for OECD countries, and he emphasizes differences in physical capital, human capital, and R&D as an explanation. Also at a disaggregated level, the U.S. Bureau of Labor Statistics (2000b) provides estimates of manufacturing productivity for 10 countries from 1979 to 1997. These growth rates, reproduced in Table 4, are typically larger than the economy-wide estimates of van Ark (1996) and show the growing divergence between the manufacturing and service sectors. An important topic for future research would be to attempt to determine whether this reflects data deficiencies, a mismeasurement problem or a real productivity phenomenon.

TABLE 2

INTERNATIONAL COMPARISONS OF INVESTMENT PER WORKER, 1970-94

	1970-74	1975-79	1980-84	1985-89	1990-94
			CONVENTIONAL CAPITAL FORMATION		
Belgium	2,000.0	3,364.4	4,435.1	6,021.2	9,156.2
Canada	2,147.5	3,610.1	5,914.9	8,332.5	10,450.1
Denmark	2,149.8	3,114.9	3,599.2	5,379.1	5,767.4
Finland	2,333.4	3,394.6	5,225.5	7,264.3	7,704.5
France	2,394.0	3,648.4	5,452.7	7,460.3	9,809.7
Germany	2,277.0	3,415.1	5,109.1	6,400.9	8,589.6
Italy	2,087.5	3,092.2	4,808.4	6,382.9	8,285.7
Japan	2,109.8	3,419.6	5,327.4	7,947.1	11,733.3
Netherlands	2,546.6	3,801.3	4,832.8	6,110.1	7,057.7
Norway	2,515.9	4,443.6	6,131.4	7,815.5	8,446.2
Sweden	1,956.2	2,771.1	3,850.9	5,625.6	6,693.5
United Kingdom	1,332.1	1,997.1	2,918.2	4,522.5	5,659.5
United States	2,695.9	3,971.2	5,755.0	7,637.5	9,717.1
Simple Mean	2,195.8	3,388.0	4,873.9	6,684.6	8,390.0
			BROADLY-DEFINED CAPITAL FORMATION		
Belgium	3,477.5	6,044.0	8,766.1	11,953.7	17,447.1
Canada	3,926.0	6,435.8	10,356.1	15,066.4	19,669.6
Denmark	3,373.2	5,215.0	6,556.2	9,368.6	11,430.7
Finland	3,275.1	5,009.0	7,886.4	11,576.8	13,895.9
France	3,549.2	5,678.9	8,835.1	12,345.9	16,414.1
Germany	3,462.7	5,632.7	8,431.1	11,197.3	15,317.7
Italy	3,029.8	4,567.0	7,627.2	10,878.4	14,905.8
Japan	2,725.4	4,570.3	7,287.6	11,199.4	16,723.5
Netherlands	4,227.7	6,900.6	8,742.0	10,900.3	12,716.5
Norway	3,723.1	6,383.3	8,992.2	12,051.6	14,080.9
Sweden	3,298.2	4,866.7	6,692.9	9,869.9	12,418.5
United Kingdom	2,317.1	3,630.9	5,722.1	8,500.2	11,281.1
United States	5,277.6	7,441.5	10,625.8	14,951.8	20,061.4
Simple Mean	3,512.5	5,567.4	8,193.9	11,527.7	15,104.8

Notes: Conventional capital formation is defined as business and non-government construction and purchases of plant, equipment, and ownet-occupied housing.
Broadly-defined capital formation includes investment in education, research and development, consumer durables, and military capital.
All values are convetted to a common currency using purchasing power parities for capital goods.

Source: Kirova and Lipsey, 1997, Tables B-1 and B-6.

TABLE 3

INTERNATIONAL COMPARISONS OF AVERAGE LABOUR PRODUCTIVITY, 1950-94

	Average Growth Rates			Relative Productivity Levels			
	1950-73	1973-87	1987-94	1950	1973	1987	1994
Australia	2.6	1.8	1.0	71.5	69.9	76.6	76.6
Austria	5.9	2.7	1.5	31.7	63.8	79.0	81.6
Belgium	4.5	3.0	2.2	46.5	68.1	88.6	96.3
Canada	2.9	1.7	1.0	75.3	78.9	85.9	85.7
Denmark	4.1	1.7	2.1	46.2	62.5	67.6	73.0
Finland	5.2	2.2	2.8	31.9	55.3	64.3	72.8
France	5.0	3.1	1.7	44.4	73.4	95.8	100.7
Germany	6.0	2.5	3.2	33.8	69.2	84.0	98.0
Greece	6.4	2.4	1.8	18.7	42.0	50.3	53.0
Ireland	4.3	3.6	5.1	29.9	42.5	59.3	78.6
Italy	5.8	2.5	2.6	32.9	64.3	77.8	86.9
Japan	7.7	3.0	2.6	15.2	44.8	57.9	64.6
Netherlands	4.8	2.6	1.5	49.3	77.4	94.7	98.0
Norway	4.2	3.4	2.6	40.4	56.3	76.4	85.4
Portugal	6.0	1.7	2.0	18.0	36.9	39.9	42.8
Spain	6.4	2.9	4.1	19.8	44.4	56.5	69.8
Sweden	4.1	1.6	1.0	53.7	73.4	78.1	78.3
Switzerland	3.3	1.2	2.6	67.7	75.9	76.5	85.4
United Kingdom	3.1	2.4	1.9	60.5	65.8	78.6	83.5
United States	2.7	1.1	1.0	100.0	100.0	100.0	100.0
Simple Mean	4.8	2.4	2.2	41.4	61.3	73.0	79.5

Notes: Average labour productivity is defined as real gross domestic product per hour worked.
Productivity levels are relative to the United States for each year.
Mean of relative productivity levels excludes the United States.
Source: van Ark, 1996, Table 1.

Dougherty and Jorgenson (1996, 1997) use the expanded neoclassical framework described above to explain differences in labour productivity for the G-7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) over the period 1960 to 1989. They conclude that investment and capital accumulation, broadly defined, are the most important sources of growth for all countries except France. Jorgenson and Yip (1999) update this work through 1995 and reach similar conclusions. These results, reported in Table 5, show that measured growth in input per capita was the dominant source of per capita output, with only the United States and Japan showing a positive contribution from TFP growth in the 1990s. In contrast, Klenow and Rodriguez-Clare (1997) use a cross-sectional regression analysis

TABLE 4

LABOUR PRODUCTIVITY GROWTH IN MANUFACTURING, 1979-97

	AVERAGE GROWTH RATE		
	1979-85	1985-90	1990-97
Belgium	6.0	2.2	2.8
Canada	3.3	0.7	2.1
France	3.0	3.4	3.6
Italy	4.6	2.3	2.2
Japan	3.5	4.3	3.0
Norway	2.4	1.4	0.8
Sweden	3.0	1.9	4.4
United Kingdom	3.1	4.1	2.4
United States	3.5	2.4	3.7
Simple Mean	3.6	2.5	2.8

Note: Average labour productivity is defined as real value added in manufacturing per hour worked.
Source: U.S. Bureau of Labor Statistics, 2000b, Table B.

and report that TFP growth accounts for nearly half of output growth for 98 countries. Hall and Jones (1999) also find large variations in the level of the Solow residual, which they attribute to "social infrastructure." While these studies examine different samples, i.e. Jorgenson and Yip include only a subset of rich countries, it would be useful to sort out the methodological differences that lead to such large empirical discrepancies.

Although data limitations typically force these studies to focus on developed countries, there has been interesting work done on the Asian economies recently. Krugman (1994), Young (1995) and Collins and Bosworth (1996) use a neoclassical approach to evaluate the potential for long-run growth in the newly industrial countries (NICs) of Asia. All three conclude that broadly-defined capital accumulation, as opposed to exogenous technical progress (measured by TFP growth), was the primary source of growth; they are thus pessimistic about future growth prospects. These claims have led to a strong debate about the relative importance of capital accumulation and total factor productivity growth as sources of success in these economies. Hsieh (1997), Rodrick (1997) and Young (1998b) provide recent views on this controversy.

TABLE 5

SOURCES OF GROWTH FOR THE G-7 COUNTRIES, 1960-95

	1960-73	1973-89	1989-95
		CANADA	
Output per Capita	3.20	2.45	-0.37
Input per Capita	1.70	2.21	0.21
Total Factor Productivity	1.51	0.23	-0.59
		FRANCE	
Output per Capita	4.26	2.04	0.92
Input per Capita	2.15	0.74	1.37
Total Factor Productivity	2.11	1.31	-0.45
		GERMANY	
Output per Capita	3.74	2.15	1.66
Input per Capita	1.24	1.25	1.78
Total Factor Productivity	2.50	0.90	-0.11
		ITALY	
Output per Capita	4.62	2.69	1.40
Input per Capita	0.79	2.42	1.49
Total Factor Productivity	3.82	0.27	-0.10
		JAPAN	
Output per Capita	8.77	2.71	1.81
Input per Capita	2.42	2.15	1.63
Total Factor Productivity	6.35	0.56	0.18
		UNITED KINGDOM	
Output per Capita	2.74	1.75	0.42
Input per Capita	0.98	1.10	1.77
Total Factor Productivity	1.76	0.65	-1.35
		UNITED STATES	
Output per Capita	2.89	1.90	0.97
Input per Capita	1.53	1.45	0.68
Total Factor Productivity	1.36	0.45	0.29

Notes: All values are average, annual growth rates.
Input per capita includes the growth contribution of capital stock, capital quality, labour hours, and labour quality.

Source: Jorgenson and Yip, 1999, Table 3.

EQUIPMENT INVESTMENT SPILLOVERS

THE POSSIBILITY THAT INVESTMENT CARRIES external productivity effects dates back at least to Arrow (1962), who formalized the idea by making productivity-enhancing experience a function of the cumulative capital stock. Wolff (1991) explores this idea and lists five channels that could link investment and technological progress: 1) investment is needed to put new inventions into practice, as in Solow (1960); 2) investment leads to organizational changes; 3) learning-by-doing, as in Arrow (1962); 4) technology offers a higher rate of return, which stimulates investment; and, 5) positive feedback effects through aggregate demand growth. Wolff (1991, Table 3) finds a statistical relationship between TFP growth and the growth of the capital/labour ratio for 7 countries over 1870 to 1979, although the relationship does not appear particularly robust. Moreover, this type of finding is subject to a Jorgenson/Griliches-type critique about using capital stock and labour hours rather than constant-quality indices of capital and labour inputs when estimating TFP growth.

In a series of provocative papers, DeLong and Summers (1991, 1992, 1993) search for productivity spillovers from equipment investment. After examining a wide variety of sample periods, specifications, statistical tests, and country samples, DeLong and Summers (1991) conclude that the social return to equipment is large and far exceeds the private return. DeLong and Summers (1992) extend this work to more countries, a later time period and additional statistical tests, and reach the same conclusion, even for subsets of relatively rich economies. While they do not model the link between investment and productivity spillovers directly, they suggest that producer experience generates production process efficiency gains, and that reverse engineering and organizational learning accompany investment in new equipment.

These results have clear implications for government intervention as a means to stimulate growth, and DeLong and Summers do not shrink from this position. In their first paper (1991), they state: "If the results stand up to scrutiny...the gains from raising equipment investment through tax or other incentives dwarf losses from any non-neutralities" (p. 485). In their second paper (1992), they go farther and conclude that "governments must avoid anti-equipment incentive policies" (p. 195). While they explicitly recognize the importance of market signals and are keenly aware of the difficulties of economic engineering, they clearly support a role for government intervention in promoting equipment investment.

However, these findings have generated considerable controversy and it is not clear that the results do, in fact, stand up to scrutiny. In the formal paper discussion, Abel (1992) questions whether the evidence is strong enough to dismiss the neoclassical view of no spillovers, while the ensuing general discussion raised many important issues dealing with causality, omitted variable bias and interpretation. Auerbach, Hasset and Oliner (1994) formalize some of these objections and point out that since equipment depreciates faster than structures, it requires a higher marginal product even in the standard neoclassical model. In a strong defence of the neoclassical model, they find "returns to equipment and structures that are fully consistent with the Solow model", and conclude that "evidence of excess returns to equipment investment is tenuous" (p. 790).

While this issue is still debated, the evidence suggests that investment in equipment primarily affects growth and productivity through the traditional, neoclassical channels. That is, investment leads to capital deepening and labour productivity, but does not create total factor productivity. More research is needed before a convincing case can be made for the existence of equipment investment spillovers and the accompanying government intervention. Until then, the simpler explanation seems the most appropriate.

R&D Investment Spillovers

Knowledge creation is an important source of productivity and economic growth, and research and development (R&D) investment generates new knowledge. While this requires expenditures and is thus rightly viewed as a type of investment, there is also a sense that knowledge capital differs from tangible capital in fundamental ways. Knowledge appears to be non-rival — many producers can simultaneously use the same idea — and its returns are hard to appropriate, i.e. spillovers may be present. As emphasized by Romer (1994), Basu (1996) and others, it is these external effects that potentially eliminate the diminishing returns to capital and make it so important to new growth theory. Hall (1996) lists a number of reasons why R&D might lead to spillovers: reverse engineering, migration of scientists and engineers, and free dissemination of public R&D. Grossman (1996), particularly on pp. 86-88, emphasizes the differences between R&D capital and tangible capital.

As a brief aside, Hall (1996) also discusses how competition may bring about lower prices for the goods of innovative firms, but Griliches (1995) distinguishes this type of pricing problem, when the transaction price does not fully reflect the marginal benefit of the innovation, from pure knowledge spillovers. While measurement problems are surely important, particularly with regard to new goods and services, it is true knowledge spillovers, defined by Griliches (1995) as "ideas borrowed by research teams of industry *i* from the research results of industry *j*" (p. 66), that may make knowledge capital fundamentally different.

The empirical literature on R&D spillovers is enormous and there are many excellent reviews.[14] Rather than repeating this effort, in this section we briefly discuss spillovers from R&D investment as a source of productivity growth in the context of new growth theories.

The micro-economic evidence indicates that R&D spillovers do matter,[15] but wide variations in results and conceptual difficulties suggest that some caution is warranted. For example, Griliches (1995) points out that the impact of R&D in industry analyses is not larger than in firm analyses (as the presence of spillovers implies) and he warns that "in spite of a number of serious and promising attempts to do so, it has proven very difficult to estimate the indirect contribution of R&D via spillovers to other firms, industries and countries" (p. 83). Given the paucity of data and the methodological problems discussed earlier, it is difficult to draw definitive conclusions from these studies.

The empirical question of R&D spillovers can also be evaluated from the macro-economic perspective and this line of research also suggests caution. In a pair of influential papers, Jones (1995a,b) tests R&D-based endogenous growth models using aggregate data on R&D inputs in industrialized countries and finds these models lacking. The empirical difficulty is due to a "scale effect" since the models typically predict that growth is proportional to economy-wide R&D investment. As can be seen in Figure 1, which plots the number of scientists and engineers employed in R&D activities and U.S. TFP growth estimates from Jones (1995b), the data do not reveal any obvious relationship.[16] Using more sophisticated econometric methods, Jones (1995b) concludes that "R&D-based models are rejected by this evidence" (p. 519). This influential critique lead to a surge of papers, e.g. Segerstrom, (1998) and Young (1998a), that removed the link between scale and growth found in many endogenous growth models. Jones (1999) provides a review.

In more recent work, Jones and Williams (1998) formalize the macro-economic impact of external R&D effects in a model similar to that used by Romer (1990). Their goal is to estimate the optimal amount of R&D investment using a general growth framework:

(10) $Y_t = F(A_t, X_t)$

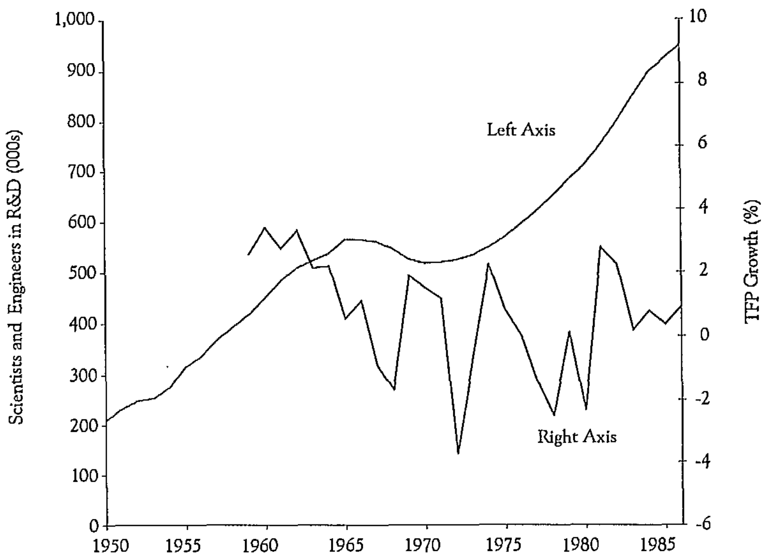
and

(11) $A_{t+1} - A_t = G(R_t, A_t)$,

where Y is output, A is the stock of knowledge, X is private inputs and R is R&D investment.

FIGURE 1

R&D SCIENTISTS AND AGGREGATE TFP GROWTH IN THE UNITED STATES, 1950-88



Source: Jones, 1995b, Figures IV and V.

The model incorporates various externalities, e.g. congestion effects through R&D duplication, knowledge spillovers, and the replacement of old ideas with new ones, that are outside the control of individual firms and thus can generate spillovers and endogenous growth. Jones and Williams (1998) calibrate the model and estimate that optimal investment in R&D is two to four times actual investment in the United States. This suggests an important role for R&D, but remains consistent with the empirical refutation of the R&D models in Jones (1995a,b).

Policy implications should also be considered. At first blush, the potential presence of R&D productivity spillovers suggests an obvious role for government intervention based on standard market failure arguments. It is not clear, however, that this is, in fact, appropriate. Boskin and Lau (1996) point out that, at the margin, R&D investment might not generate spillovers; Griliches (1995) notes a strong premium for company-financed R&D over government supported R&D projects; Hall (1996) reports that the excess private returns to federal R&D are zero in the United States and other countries; and Aghion and Howitt (1992) provide a theoretical argument where over-investment in R&D occurs in markets where competition is imperfect. Jones and Williams (1998), Boskin and Lau (1996), Grossman (1996) and Hall (1993, 1996) discuss this point at some length, and the enormous difficulties in measuring the impact of R&D investment prevent strong policy prescriptions.

A final area of interest is the role of R&D spillovers in an international context. For example, Coe and Helpman (1995), working with a more general class of models developed by Grossman and Helpman (1991), argue that cross-country R&D spillovers are an important source of productivity growth. That is, productivity levels for a given country appear correlated with past R&D investments of close trading partners. However, Keller (1998) disputes these findings empirically after repeating the Coe and Helpman exercise with random trading patterns and finding more explanatory power than with the observed bilateral trade data.

Keller (1998) also makes a second critique, perhaps more relevant to this paper. In his discussion of the general models of Grossman and Helpman, Keller points out that productivity spillovers exist if "the importing country pays less than the intermediate good's full marginal product" (p. 1470). This is reminiscent of the distinction made by Griliches (1995) between true spillover and conventional pricing problems. While very difficult to do in practice, if all attributes and quality characteristics were correctly priced, then the increased quality or variety of intermediate inputs would not be a source of productivity spillovers.

THE COMPUTER PRODUCTIVITY PARADOX

OVER THE LAST FEW DECADES investment in high-tech equipment, particularly computers, exploded but aggregate productivity growth remained sluggish until 1995. This apparent contradiction, the so-called "computer productivity paradox," disappointed many observers and initiated a broad research effort at both the macro and micro levels.[17] Despite difficult measurement and identification issues, this work has generated interesting results and several alternative explanations.[18] Although the resurgence of productivity in the United States during the late 1990s has partially resolved the puzzle, it is nonetheless worthwhile to discuss the link between IT investment and productivity growth.

The defining characteristic of the information technology (IT) revolution is the enormous improvement in the quality of computers, peripherals, and related high-tech equipment. As epitomized by Moore's Law — the doubling of the complexity of a computer chip every 18 months — each generation of new computers easily outperforms models considered state-of-the-art a few years earlier. Based on the early hedonic work of Cole, Chen, Barquin-Stolleman, Dulberger, Helvacian and Hodge (1986), the U.S. Bureau of Economic Analysis (BEA) developed constant-quality price deflators for computer and peripheral equipment in 1986 to translate the massive quality improvements into increased real investment and real output. These series, now incorporating more recent estimates from the Bureau of Labor Statistics' Producer Price Index program, show an average annual decline in the constant-quality price of computer investment of more than 18 percent over nearly four decades. Assuming that this sort of quality adjustment is appropriate,[19] the first question to ask is what does basic economic theory predict from such dramatic changes in relative prices?

Jorgenson and Stiroh (1999, 2000) isolate the importance of computer investment in the U.S. economy and emphasize the rapid substitution of profit-maximizing firms and utility-maximizing consumers towards relatively cheap computer inputs and away from other inputs like labour and other forms of capital. As shown in Table 6, taken from Jorgenson and Stiroh (2000), the quality-adjusted investment price of computer investment fell by 14.6 percent over 1990-95 and by 27.6 percent over 1995-98; the user cost fell by 10.6 percent and 20.1 percent, respectively, over the same periods. Prices of non-IT capital inputs and labour rose over that period. In response to these enormous relative price changes, U.S. firms have invested heavily in computers and accumulated them much more rapidly than other inputs — the growth of computer capital services was 34 percent per year over 1995-98.

Haimowitz (1998), Jorgenson and Stiroh (1999, 2000), Oliner and Sichel (1994, 2000) and Whelan (1999) incorporate these investment trends into a neoclassical growth accounting framework to estimate the growth contribution of computers, defined as the share-weighted real growth rate, as in Equation (3). Recent estimates show that computers and other forms of information technology have played a key role in the resurgence of productivity growth in the United States. Oliner and Sichel (2000) estimate that information technology (computer hardware, software, and telecommunications equipment) contributed 0.8 percentage points to output growth between 1990 and 1999, while Jorgenson and Stiroh (2000), whose results are reproduced in Table 1, estimate the contribution of information technology to 0.53 from 1990 to 1998.[20] IT is now making a meaningful contribution to U.S. economic growth; the massive substitution has led to a large contribution to growth relative to other types of capital goods.

To understand the impact on productivity, one must make a careful distinction between the *use* of computers and the *production* of computers. Since computers are both the output of one industry (the computer-producing industry) and an input to others (the computer-using industries), one should expect different impacts across industries. Since the same constant-quality deflator is used to estimate real computer investment as an output (part of GDP as a final demand good) and as an input (part of the capital stock), the massive quality improvements

TABLE 6

AVERAGE GROWTH RATES OF SELECTED INPUTS AND OUTPUTS, 1990-98

	1990-95		1995-98	
	PRICES	QUANTITIES	PRICES	QUANTITIES
		OUTPUTS		
Private Domestic Output	1.70	2.74	1.37	4.73
Other	2.01	2.25	2.02	3.82
Computer and Software Consumption	-21.50	38.67	-36.93	49.26
Computer Investment	-14.59	24.89	-27.58	38.08
Software Investment	-1.41	11.59	-2.16	15.18
Communications Investment	-1.50	6.17	-1.73	12.79
Computer and Software CD Services	-19.34	34.79	-28.62	44.57
		INPUTS		
Total Capital Services	0.60	2.83	2.54	4.80
Other	1.00	1.78	4.20	2.91
Computer Capital	-10.59	18.16	-20.09	34.10
Software Capital	-2.07	13.22	-0.87	13.00
Communications Capital	3.10	4.31	-7.09	7.80
Total Consumer Durable Services	1.98	2.91	-0.67	5.39
Non-computer and Software	2.55	2.07	0.54	3.73
Computer and Software Services	-19.34	34.79	-28.62	44.57
Labour	2.92	2.01	2.80	2.81

Source: Jorgenson and Stiroh, 2000, Table 1.

in computers contribute to faster output growth in the computer-producing industry and faster input accumulation in the computer-using industries. Thus, one should expect rapid capital accumulation and ALP growth in computer-using industries, and technical progress and TFP growth in the computer-producing industry. This fundamental dichotomy is apparent in the seminal article of Solow (1957), but it has often been overlooked in discussions of the computer productivity paradox.

Consider the productivity of firms and industries that invest in and use computers. As in Equation (4) and as emphasized by Stiroh (1998a), computer investment contributes directly to ALP growth through the traditional capital accumulation channel. By providing workers with more and better capital equipment to work with, computer investment should raise labour productivity in industries that use computers. However, TFP will not be directly affected by computer investment since all contributions to productivity will be captured by the capital accumulation term. Computer-use increases TFP only if there are non-traditional effects like production spillovers or network externalities, or if inputs are measured incorrectly.

Now consider the productivity of firms and industries that produce computers and other high-tech goods. These industries are experiencing fundamental technical progress — the ability to produce more output from the same inputs —, which should contribute to both TFP and ALP growth.

The computer-using and computer-producing effects are evident in the aggregate studies mentioned above, but the empirical evidence has been mixed when moving beneath the aggregate data. In terms of computer use and ALP growth, Brynjolffson and Hitt (1995) report large productivity effects from computers; Gera, Gu, and Lee (1999) and McGuckin and Stiroh (1998) find a positive impact of computer investment in most industries; McGuckin, Streitwieser and Doms (1998) report higher productivity in manufacturing plants that use high-tech equipment; and Steindel (1992) reports that high-tech equipment played a meaningful role in U.S. manufacturing industries during the 1980s. Berndt and Morrison (1995) report a negative impact. In terms of TFP growth, Siegel and Griliches (1992) and Siegel (1997) estimate a positive impact of computer investment, while Berndt and Morrison (1995) and Stiroh (1998a) report either a negative or an insignificant relationship.

As for the computer-producing industry, the data are consistent with the notion that fundamental technical progress is the driving force in the production of these new high-tech investment goods. BLS (2000), Stiroh (1998a), Jorgenson and Stiroh (1999, 2000) and Oliner and Sichel (2000) all report strong industry TFP growth in the high-tech producing industries, e.g. U.S. SIC 35 and 36. As an important caveat, however, Triplett (1996) shows that one must incorporate quality adjustments for all inputs to correctly allocate TFP across sectors. Since the BEA recently incorporated constant-quality price deflators for semi-conductors into the U.S. national accounts, an obvious area for future research would be to update industry TFP estimates using the new input deflators.

There is also a large micro-economic literature that estimates with econometric tools the returns to computer or information technology (IT) investment across firms or industries.[21] This research, e.g. Gera et al. (1999), Brynjolffson and Hitt (1993, 1995, 1996), Lehr and Lichtenberg (1999) and Lichtenberg (1995), has typically estimated higher returns on computers than on other forms of capital. In contrast, Berndt and Morrison (1995) and Morrison (1997) report evidence of over-investment in high-tech capital goods.

The findings of super-returns are not necessarily inconsistent with the neoclassical model, and one does not need alternative answers like spillovers or network effects to justify large relative returns. Rather, computers must have high marginal products because they obsolesce so rapidly.[22] That is, while computers may have a low acquisition price, rapid obsolescence makes them expensive to use. Moreover, recent work by Brynjolffson and Yang (1997) suggests that much of the "excess returns" to computers actually represent returns to previously unspecified inputs such as software investment, training, and organizational change that accompany computer investment. Thus, the empirical evidence from the micro studies leads back to the neoclassical framework.

This still leaves the question of why ALP growth remains slow in some industries, and many authors have suggested persistent measurement problems to be the culprit since computers are highly concentrated in the service sector, where output and productivity are notoriously hard to measure. For example, Triplett (1999b) and Stiroh (1998) report that most IT investment is in service- and finance-related industries; some commentators, e.g. Diewert and Fox (1999), Griliches (1994) and Maclean (1997), have suggested that measurement errors may play a substantial role in the computer productivity paradox.

Mismeasurement can be important in two ways. First, Griliches (1994) points out that computer-intensive service industries are steadily growing as a share of developed economies, so any existing measurement error now leads to a larger understatement of aggregate productivity. However, Sichel (1997a) evaluates this channel empirically and concludes that the growing share of the service sector can only account for a small part of the productivity slowdown. Second, computers may have worsened measurement problems within computer-intensive sectors. While the BLS has made major improvements in the U.S. CPI to reduce bias, it is possible that the growing role of computers through the proliferation of new products, input substitution, and product improvements may have caused the existing measurement problems in some industries to worsen. Dean (1999) and Gullickson and Harper (1999) discuss measurement problems in U.S. service industries.

As an important caveat, however, Baily and Gordon (1988) argue that many computer services are sold as intermediate goods, so their impact on final demand (GDP) is likely to be small. In addition, Triplett (1999b) argues against the "new product" explanation. Nonetheless, this is an important area for future research since we essentially ignore if measurement problems have worsened in computer-intensive service industries.

A second common explanation is that computers are still relatively new and it may just be a matter of time until they fundamentally change the production process and usher in a period of faster productivity growth. David (1989, 1990) has received considerable attention for drawing a parallel between the slow productivity benefits from electricity and from the computer age. However, Triplett (1999a) argues convincingly that the massive decline in computer prices, and hence the diffusion pattern, is unprecedented, and he cautions against such analogies. Moreover, computers are no longer really a new investment — the first commercial purchase of a UNIVAC mainframe computer occurred in 1954, and computer investment has been a separate entry in the U.S. national accounts since 1958 —, so the critical mass hypothesis is beginning to lose credibility.[23]

A final explanation for the slow productivity growth in some industries is simply that computers are perhaps not that productive. Anecdotes abound of failed systems, lengthy periods of downtime, unwanted and unnecessary "features" and time-consuming upgrades, all of which can reduce the productivity of computer investment. Gordon (1998, 2000) provides a summary of this pessimistic view. On the other hand, this interpretation implies enormous investment errors by businesses and is not consistent with much of the empirical literature.

Despite some lingering debate, the computer revolution appears to be largely a neoclassical story of relative price declines and substitution. Technical change in the production of high-tech goods lowers their relative prices, induces massive high-tech investment and is ultimately responsible for changing the behaviour of households and firms. However, these benefits accrue primarily to producers and users of high-tech investment goods with little evidence of large spillovers from computers. Future research should focus on the impact of computers in the hard-to-measure service sector in a broader context that includes associated investments in software and training. Only by including all inputs can one correctly measure the productivity and returns from the computer revolution.

Labour Issues

THE IMPACT OF INVESTMENT ON LABOUR has been an area of much policy interest at least since the turn of the century, when the Bureau of Labor Statistics (BLS) first began publishing labour productivity estimates in response to an outcry that new machinery was replacing jobs. The question of capital/labour substitution or complementarity is important since it directly affects labour market outcomes and living standards. Recent work has focused on whether new investment is biased towards certain types of labour and affects the wage premium for higher skills.

The impact of new investment and technological change on the composition and quality of the labour force is theoretically ambiguous. Griliches (1969), for example, argues that capital is complementary to high-skill labour due to increasing education requirements to operate new equipment, while Braverman (1974) and Levy and Murnane (1996) claim that investment in high-tech equipment "de-skills" jobs, allowing tasks to be reassigned to lower levels, and thus reduces the average skill level of labour. Likewise, the nature of skill-biased technological change, which is defined as an exogenous increase in the relative demand for skilled workers at a given relative wage ratio, is an empirical question.

Berman, Bound and Griliches (1994) examine equipment-skill complementarity and conclude that skill-biased technological change is the dominant force behind the shift toward non-production workers in U.S. manufacturing during the 1980s. In particular, they find a positive correlation between skill upgrading and investment in computers and R&D, which they use as indicators of technological change. Berman, Bound and Machin (1998) extend this work to developed countries and obtain similar results; Betts (1997) examines Canadian manufacturing industries and reports evidence of skill-biased technological change; Kahn and Lim (1998) report that productivity growth was concentrated in skill-intensive manufacturing industries; finally, Machin and Van Reenen (1998) find a significant link between skill upgrading and R&D intensity.[24] It is not clear, however, that this really represents skill-biased technological change rather than neoclassical capital-skill complementarity. In Berman et al. (1994) and Machin and Van Reenen (1998), for example, computer and R&D investments are used as the primary indicators of technology, but an alternative perspective would label these as specific types of investment and capital goods.

A related issue is how investment affects the wage structure. In the neoclassical model, investment and capital accumulation raise labour productivity and, since all inputs receive factor payments equal to their marginal product, this implies a direct increase in wages. Recent research has noted that new investment, particularly in information technology, is more likely to be used by highly educated workers and thus may be contributing to an increase in the wage premium associated with education. Likewise, skill-biased technological change should increase the productivity and returns to high-skill labour.

Krueger (1993) examines this issue and estimates a 10-15 percent wage premium for computer use and concludes that increased computerization accounts for a large share of the higher returns to education. In a persuasive critique, however, DiNardo and Pischke (1997) reinterpret Krueger's results as evidence of unobserved heterogeneity that may be unrelated to computers *per se* but translates into rewards in the labour market. Likewise, Bartel and Sicherman (1997) find that the wage premium primarily reflects the sorting of workers and unobserved characteristics. Murphy, Riddell and Romer (1998) report that technological progress has increased the relative demand for skilled workers in both the United States and Canada. Autor, Katz and Krueger (1998) point out that the shift toward more-skilled workers has been going on for decades and find that recent increases in high-skill workers are fastest in computer-intensive industries, although they caution about a possible reverse causality.

Consistent with standard economic theory, these results show a wage premium for education and skills. While there is some disagreement about whether this reflects unobserved worker attributes, mismeasured complementary investment or skill-biased technological change, the empirical facts are in agreement. Moreover, the distinction between capital quality and technology is to some extent semantic, which has generated some confusion. This issue is addressed next.

THE RENEWED "EMBODIMENT CONTROVERSY"

ECONOMISTS HAVE SPENT CONSIDERABLE EFFORT trying to unravel the sources of technological change and productivity growth. As discussed above, the modern neoclassical framework explicitly adjusts inputs for quality change to better measure exogenous technological progress, while the new growth theory attempts to explain technological progress as the result of spillovers, increasing returns, etc. An alternative perspective, however, argues that technological progress is embodied in new machinery and equipment and thus requires investment to affect output and productivity. In challenging papers, Greenwood, Hercowitz and Krusell (1997) and Hercowitz (1998) recently brought this debate back to center stage and rekindled the "embodiment controversy."[25]

The embodiment idea goes back at least to Solow (1960), who suggested that technical change is "embodied" in new investment goods, which are therefore needed to realize the benefits of technical progress. In response, Jorgenson (1966) showed that this is indistinguishable from the neoclassical view of exogenous technological change, depending critically on how investment prices are calculated. That is, by adjusting capital inputs for quality change, output and productivity growth are attributed to input accumulation and not to the total factor productivity (TFP) residual. This correspondence has led to some semantic confusion since the same force can be alternatively labelled input accumulation or TFP growth depending on how input and output price deflators are incorporated. An important conclusion of Jorgenson is that investment both as an input (via capital accumulation) and as an output should be adjusted for changes in quality.

In the debate on the appropriateness of quality-adjusted deflators for computers, Hulten (1992) presents a detailed growth accounting derivation and shows that failure to account for quality changes in investment amounts to "suppressing the quality effects into the conventional total factor productivity residual (p. 976)." It should be pointed out that this type of quality adjustment reflects the improved productivity of particular assets and is different from the substitution between heterogeneous capital assets described above.

Greenwood et al. (1997) and Hercowitz (1998) recognize this perspective, but argue against it, attributing 60 percent of postwar productivity growth to investment-specific technological change that is conceptually distinct from capital accumulation and disembodied technological change. In addition, they claim that constant-quality price indices are appropriate for deflating investment inputs, but not for deflating investment as an output. In this welfare-based perspective, real output should be measured in foregone consumption units, so that nominal investment should be deflated by the price of consumption goods.

As evidence, Greenwood et al. (1997) point out that Gordon (1990) estimated that the relative price of equipment in the United States has fallen 3 percent annually in the postwar era. This is a puzzling appeal to evidence, however, since the goal of Gordon's monumental effort was to develop better output price measures; he explicitly states that "both input price and output price indexes treat quality change consistently (p. 52)." Moreover, the Greenwood et al. approach severs the link between the sources of growth (labour, capital and technology) and the uses of growth (consumption and investment goods) that constitute a complete model of production and welfare.

The debate about embodied and disembodied technological progress clearly raises a difficult theoretical issue and it is far from settled. It seems that a resolution of this debate will require a complete sectoral model that explicitly distinguishes total factor productivity in the production of investment goods from labour productivity in the use of investment goods.[26] However, a full resolution of this controversy is beyond the scope of our review paper and remains an important area for future research.

Plant-Level Evidence on Investment and Productivity

THE RECENT AVAILABILITY OF LARGE LONGITUDINAL DATA SETS, e.g. the U.S. Longitudinal Research Database (LRD) housed at the U.S. Census Bureau, has opened up a new channel for exploring the relationship between investment and productivity.[27] Much of the work discussed above is at the industry or aggregate level, which can hide important variations in economic relationships. Likewise, theoretical and empirical work by Caballero, Engel and Haltiwanger (1995) and others shows the importance of adopting a micro perspective on investment dynamics.[28] Since the LRD includes an enormous number of manufacturing plants observed at five-year intervals over a long period of time, it can provide opportunities for new insights on the link between investment and productivity.

In an influential paper, Baily, Hulten and Campbell (1992) explore the dynamics of plant productivity growth and find strong firm effects, an important role for reallocation from low-productivity to high-productivity plants, and a strong association between relative productivity and relative wages. They also find some evidence of "vintage effects," as old plants are systematically less productive than new plants, although the contribution of capital to output is small. Jensen, McGuckin and Stiroh (2001) present more recent evidence on this type of vintage effect as recent cohorts with access to a modern generation of plant and equipment capital enter with higher productivity levels.

Power (1998) uses the LRD to explore the relationship between investment and productivity. After controlling for relevant characteristics, she finds no evidence of correlation between productivity and measures of recent equipment investment. These remarkable results suggest that other plant characteristics, e.g. location and management, are more important determinants of productivity, which puts into question the importance of investment as a source of productivity. The counter-intuitiveness of these results, however, requires that much more work be done before they can be taken as a stylized fact or incorporated into policy. In particular, these results need to be reconciled with the theoretical literature that makes opposing predictions, and verification with other data sets and alternative approaches is needed.

DETERMINANTS OF INVESTMENT

AS A FINAL NOTE, it should be pointed out that this paper has focused on the impact of investment on productivity, but it has not addressed the microeconomic factors, e.g. tax policy, cost of capital components or capital market features, that drive investment decisions. That is, the paper examines the effects of investment, but not its causes. This is clearly important for understanding the role that investment plays as a source of growth and there is a large literature exploring this issue. Cummins, Hassett and Hubbard (1994), Hassett and Hubbard (1996) and Hubbard (1998) provide recent reviews and list the relevant papers.

CONCLUSIONS AND FUTURE RESEARCH

THIS PAPER PROVIDES A BROAD OVERVIEW of recent theoretical developments that link investment to productivity and summarizes the corresponding empirical evidence. While different schools of thought emphasize alternative transmission mechanisms and some empirical results are inconclusive, one conclusion appears universal — broadly-defined investment is the crucial factor that raises productivity, generates economic growth and raises living standards.

The many contributors discussed above have made enormous progress in furthering our understanding of this critically important topic, but many questions remain unanswered and much more needs to be done. The remainder of this section outlines several research questions that appear to be both conceptually relevant and feasible.

How important are the non-traditional effects that form such a crucial part of the new growth literature? The current evidence suggests that the benefits of investment largely accrue to the economic agents who undertake it, but it is certainly possible that difficult measurement and identification issues obscure the importance of spillovers. A number of prominent researchers have focused on this aspect with some success, but more evidence from a variety of methodologies and data sets is needed. This is an especially relevant topic since it leads directly to policy issues like tax incentives and subsidies for certain types of investment activities, and to a potential role for government in the provision of specific forms of capital like infrastructure or R&D.

What is the contribution of different types of investment and capital to productivity growth? It seems clear, on both theoretical and empirical grounds, that the broader definition of investment is the appropriate concept to use. For example, investment in human capital involves a trade-off of current consumption for future consumption and it would be misleading to dismiss this contribution. Since the various components of investment are highly correlated in practice, however, any attempt to measure the productivity impact of any type of investment must be based on a broad specification, with appropriate quality adjustments. Failure to do this will lead to biased estimates of the importance of the included variables and can translate into consequential policy errors.

Why is service-sector productivity still relatively slow? Despite massive investments in high-tech goods, measured labour productivity growth in the service sector remains far below that of manufacturing in most developed countries. Future research should attempt to determine whether this reflects data deficiencies, e.g. a lack of surveys and censuses, worsening measurement problems or a real divergence in productivity trends. A fruitful research avenue would reconcile aggregate and industry results with micro-economic studies, either from newly created longitudinal data sets for services or firm-specific studies from alternative sources. For example, many studies examine the U.S. banking industry because of the large amount of data available from regulatory agencies. These micro-data sets offer an alternative way to explore the plausibility of the slow productivity growth reported at the aggregate and sectoral levels.

Are the rapid quality improvements and corresponding evolution of U.S. computer prices unique? Much of the empirical work on the computer productivity paradox has been done in the United States, where the dominant empirical fact is the massive decline in the quality-adjusted price of computers. Wykoff (1995) shows that a dominating trend like this one has a strong impact on measured productivity growth, even at the sectoral level, and thus must be accounted for in any international comparison. According to Gust and Marquez (2000), many industrialized countries still do not use hedonic methods in calculating computer price indices. Future research that compares the productivity impact of computers across countries must address this deflation issue and determine the proper way to account for differences in pricing methodologies. For example, since the United States is a major exporter of computer equipment, is it appropriate to use the U.S. deflator in other countries? Alternatively, less-developed countries may be purchasing a different mix or vintage of equipment and thus the U.S. deflator may overstate quality improvements in these countries. Ultimately, this question can only be addressed empirically on a country-by-country basis.

What do micro-data sets tell us that aggregate data cannot? With the recent creation of longitudinal data sets, there has been an outpouring of new research showing that aggregate data hide much of the story behind productivity dynamics. In addition, this research has raised new questions and areas for future work. For example, some micro studies report that investment does not lead to productivity at the plant level, a result that needs to be examined further and substantiated across alternative methodologies and data sets.

How real is the embodiment controversy and what is the proper resolution of this issue? Forty years after Solow's work, there is still heated debate about the relative importance of embodied and disembodied technical progress. Is this debate illusory in the sense that the competing views are simply labelling the same force differently? Or are there deeper, conceptual differences underpinning this debate? While difficult, a useful theoretical contribution would model this debate in a common framework that allows each perspective to be examined and semantic differences separated from real ones.

ENDNOTES

1 See Jorgenson (1996) for a discussion of the growth theory revival, Barro and Sala-i-Martin (1995) for a thorough analysis of the neoclassical framework, Aghion and Howitt (1992) for a detailed review of different strands of the new growth theory, and Klenow and Rodriguez-Clare (1997) and Mankiw (1995) for a comparison of neoclassical and endogenous growth models.

2 This also directly affects living standards, measured as per capita income. See McGuckin and van Ark (1999) for international estimates of how they differ empirically due to differences in unemployment rates, labour force participation rates, etc.

3 For example, Stiroh (1998b) traces the evolution of the long-run projection models used by the U.S. Government, e.g. the Social Security Administration, the Congressional Budget Office, the Office of Management and Budget, and the General Accounting Office, and shows that all are firmly embedded in this neoclassical tradition.

4 Mankiw (1995), particularly on pp. 280-289, discusses empirical objections to the neoclassical model.

5 It should be pointed out that Solow (1957) explicitly favoured using the annual flow of capital services, but data limitations forced him to use the "less utopian measures of the stock of capital goods (p. 313)."

6 Griliches (1996) provides a summary of the early work on human capital.

7 In earlier work, Lucas (1988) incorporates human capital into a growth model, but explicitly includes an external spillover effect. Consequently, this model is discussed below in the context of the new growth theory.

8 Griliches (1994, 1995) and Hall (1996) provide detailed surveys of the empirical literature.

9 The conference proceedings in Munnell (1990) explore these issues. Aaron (1990), in particular, is a good example of important critiques of Aschauer's work. Gramlich (1994) provides more recent reviews.

10 Mankiw (1995) makes a similar point when he discusses the "degrees of freedom" problem in the interpretation of cross-sectional growth regressions. Wolff (1996) is a notable exception and includes R&D spending, mean education attainment and the age of the capital stock in an attempt to unravel the productivity slowdown.

11 Technically, long-run growth in per capita variables results if there are constant returns to all accumulated inputs.

12 An alternative example is that firms may produce with production functions that exhibit increasing returns. In this case, no externalities are needed.

13 The following simplifications follow Romer (1994), who summarizes the evolution of endogenous growth models.

14 Good, Nadiri and Sickle (1996), Hall (1996) and Griliches (1992, 1994, 1995) are recent examples.

15 Good et al. (1996) state that "most of these recent studies point in the direction that there is some effect of R&D spillovers on the productivity growth of the receiving industry or economies" (pp. 38-39), while Griliches (1995) states that "In spite of many difficulties, there has been a significant number of reasonably well-done studies all pointing in the same direction: R&D spillovers are present, their magnitude may be quite large, and social rates of return remain significantly above private rates." (p. 72)

16 Griliches (1994) anticipates this finding when he notes that there is no reason to believe that knowledge externalities have slowed down in the last twenty years when aggregate productivity growth slowed.

17 Ultimately, one would like to answer a difficult counterfactual question — how fast would labour productivity have grown in the absence of computers — but this is very difficult indeed. For example, the explosion of computing power occurred roughly contemporaneously with the well-known productivity slowdown and one must distinguish the productivity impact of computers from the host of factors examined in that context. See *The Decline in Productivity Growth*, Federal Reserve Bank of Boston Conference Series No. 22 (1980), Baily and Gordon (1988), Baily and Schultze (1990) and Wolff (1996) for examples of the large literature on the productivity slowdown.

18 Brynjolffson and Yang (1996) summarize recent empirical work, Sichel (1997b) provides a broad analysis of the impact of computers and Triplett (1999a) presents a detailed critique of common explanations.

19 There is general agreement that adjusting computers for quality changes is appropriate, but there are dissenting views. Denison (1989), for example, argues specifically against constant-quality price indices for computers.

20 These empirical differences primarily reflect the time periods and output concept. Jorgenson and Stiroh (1999, 2000) use an extended output concept that includes imputations for consumers' durables and housing, while Oliner and Sichel (2000) focus on the non-farm business sector.

21 Brynjolffson and Yang (1996) provide a review.

22 Oliner (1993, 1994) presents details on computer depreciation.

23 Gordon (1989) provides a history of the early evolution of computer prices and diffusion.

24 On a historical note, Goldin and Katz (1998) report evidence of capital-skill complementarity and skill-biased technological change in the United States from 1909 to 1940.

25 van Ark (1996) discusses the controversy in the context of international productivity comparisons.

26 Note that Greenwood et al. (1997) calibrate a simple two-sector model, but do not fully integrate it to their empirical work on the sources of growth.

27 Jensen and McGuckin (1997) provide a review of the empirical work.

28 Caballero (1997) provides a review of this literature.

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14

Does Under-investment Contribute to the Canada-U.S. Productivity Gap?

SUMMARY

MANY COMMENTATORS HAVE POINTED to the productivity gap between Canada and the United States as evidence of a Canada-U.S. investment gap. In this paper, we examine whether this hypothesis is plausible using a variety of different models of growth, and a variety of different data sources. We find, as others have done before us, that Canada does indeed lag behind the United States for investment in machinery and equipment, and investment in R&D, although not for investment in overall physical capital or in human capital. However, it is by no means clear that the investment gaps we have found could be responsible for much of the Canada-U.S. productivity gap. The gap in machinery and equipment investment appears to be largely offset by the greater quality of the Canadian machinery and equipment capital stock. In addition, the R&D investment gap appears to be too small to be responsible for much of the productivity gap, unless R&D spillovers are both implausibly large and confined within national boundaries.

INTRODUCTION

IN A WIDELY QUOTED ADDRESS, Professor Pierre Fortin (1999) has argued that productivity levels in Canada are significantly below those in the United States, and that the gap has actually widened slightly over the last twenty years. Fortin argues that we would normally expect Canadian productivity levels to be catching up to U.S. levels, and so the persistence of the productivity gap should be of particular concern for public policy.

What might be behind this productivity gap? Fortin claims that the principal culprit is under-investment: in particular, under-investment in machinery and equipment, and in research and development (R&D). This diagnosis has been echoed by other commentators, including Fairholm (1999), who places particular emphasis on Canada's low investment in machinery and equipment.

In this chapter, we take a closer look at whether under-investment can explain why productivity in Canada is lower than in the United States. We should make clear at the outset that the purpose of our study is not to examine whether there is productivity gap between Canada and the United States. A recent comparative study by Industry Canada researchers indicates that "the gap in the level of productivity between Canadian and U.S. industries has remained virtually unchanged since 1973" (Gu and Ho, 2000, p. 172).

Therefore, we shall focus instead on three issues: what measures of investment matter most for productivity; whether Canada has an investment gap; and whether that investment gap is wide enough to explain the lower level of productivity in Canada.

The first issue is conceptual in nature, as the answer depends very much on the underlying growth model that one assumes. Rather than arguing for a particular model of growth, the first section of the study examines different growth models in order to establish the circumstances under which an investment gap might lead to a gap in labour productivity. We then go on to examine in the next section the second, more empirical issue — whether or not Canada actually has an investment gap — by comparing various investment and capital stock measures for both the United States and Canada in recent years. The last section concludes the study by examining the third issue: whether the data support the hypothesis that under-investment is responsible for Canada's productivity gap with the United States.

CONCEPTUAL ISSUES – HOW DOES INVESTMENT AFFECT PRODUCTIVITY LEVELS?

WE START BY OUTLINING THE RELATIONSHIP between investment and productivity in three different classes of model: the basic neoclassical growth model; an augmented neoclassical growth model in which technological change is partly embodied in capital; and endogenous growth models, in which technological change is explicitly modelled rather than being assumed exogenous.

THE BASIC NEOCLASSICAL GROWTH MODEL

WE BEGIN WITH A SIMPLE NEOCLASSICAL GROWTH MODEL in which long-term growth is driven by exogenous, disembodied technological change. Let an economy's production function be given by:

(1) $Y = A \cdot K^{\alpha} \cdot L^{1-\alpha}$,

where Y is output, K is the capital input, L is the labour input and A is total factor productivity (TFP). We define labour productivity, Y/L, as y, and capital intensity (the capital-labour ratio), K/L, as k. Let's assume for simplicity that the elasticity of output with respect to capital, α, is the same in both countries. Then, labour productivity in Canada relative to the United States can be written as:

$$(2) \quad \frac{y_{Can}}{y_{US}} = \frac{A_{Can}}{A_{US}} \left(\frac{k_{Can}}{k_{US}} \right)^{\alpha}.$$

In this model, a U.S.-Canada productivity gap could come from either a difference in TFP levels or a difference in capital intensity (or both). The importance of capital intensity will depend critically on the output elasticity of capital parameter, α, which one would expect to be fairly similar in Canada and the United States (around one-third, if proxied by the share of capital in national income). If this elasticity is low, then it will take a large difference in capital intensity to affect relative labour productivity between the two countries.

Interpreting the Model in the Long Run

An important element to bear in mind when interpreting an expression such as Equation (2) is that in the basic neoclassical model, capital intensity is not an exogenous variable. On the contrary, it is an endogenous variable partially determined by the level of TFP in long-run equilibrium. In a simple model,[1] equilibrium capital intensity is reached when the marginal product of capital is equal to the real after-tax interest rate, r, so that

$$(3) \quad MP_K = \alpha \cdot \frac{y}{k} = \alpha \cdot \frac{A \cdot k^{\alpha}}{k} = r.$$

In a closed economy, r will depend on consumers' discount rates and the rate of taxation on capital. Solving Equation(3) for equilibrium capital intensity gives:

$$(4) \quad k = \left(\frac{\alpha}{r} \right)^{\frac{1}{1-\alpha}} \cdot A^{\frac{1}{1-\alpha}}.$$

Putting Equation (4) into Equation (2) produces the following expression:

$$(5) \quad \frac{y_{Can}}{y_{US}} = \left(\frac{A_{Can}}{A_{US}} \right)^{\frac{1}{1-\alpha}} \cdot \left(\frac{r_{US}}{r_{Can}} \right)^{\frac{\alpha}{1-\alpha}}.$$

Thus, in long-run equilibrium, Equation (5) indicates that a greater share of any Canada-U.S. productivity gap is explained by TFP differences than would be apparent from an expression such as Equation (2). Indeed, if real interest rates in the two countries were equal, such as would occur if Canada were a small open economy vis-à-vis the United States and capital taxes were the same in the two countries, then all of the long-run productivity differences in this simple model would be due to technology differences.

Issue: Investment Share or Capital Stock?

Discussions of under-investment often focus on investment shares rather than the capital stock. For example, Fortin (1999, p. 85, Figure 19) presents a chart of investment to (trend) GDP showing that investment as a percentage of GDP is lower in Canada than in the United States. A similar approach is adopted by Kirova and Lipsey (1998). This choice is usually made on empirical grounds, because investment shares are often easier to construct than capital stock measures. Nevertheless, from a conceptual standpoint, capital stock measures are preferable, because in a production function such as Equation (1) it is differences in the capital stock that produce differences in productivity. Although a lower investment rate may well portend a smaller capital stock in the future, it is not as relevant as the current capital stock for examining current differences in output per worker. However, other factors may explain why output per worker varies so enormously across countries. Besides differences in physical capital, differences in institutions, regulations or government policies could also affect output per worker.[2] Furthermore, investment shares may be a misleading indicator even of the growth in the capital stock. If we define investment as I, then the rate of growth of the capital stock is given by:

$$(6) \quad \dot{k} = \frac{I}{Y}\frac{Y}{K} - \dot{L}\,.$$

It is quite clear from Equation (6) that two countries could have the same investment share I/Y, but different growth rates of the capital-labour ratio and, therefore, of productivity if either employment growth or the output-capital ratio differs across countries.

Issue: How Broadly Should We Define Capital?

In his above-mentioned address, Pierre Fortin concentrates on non-residential business investment. However, there is no reason in principle why we could not broaden the definition to include other forms of investment, such as public infrastructure investment, investment in housing by consumers, and even investments in land and inventories. All of these activities increase an appropriately defined capital stock and lead to an increased flow of output over time. Also, it is important to broaden the definition of investment to include the stock of human capital. Even in a neoclassical model, investment in human capital will lead to an increase in the level of output, and the stock of human capital should, in principle, be included in capital stock measures. Whether we include other forms of physical or human capital, broadening the definition of capital should also affect the way we define output. So, for instance, if investment in consumer durables is included in aggregate investment, services from consumer durables should also be considered as part of the output.[3]

Note that there is no reason, in a neoclassical model, to privilege investment in machinery and equipment as somehow being more important for productivity than any of the other form of investment mentioned above. Perfect competition in the market for capital should ensure that the marginal products of all types of capital goods are equalized, provided they are subject to the same tax and depreciation rates.[4]

Issue: Cyclical Adjustments

One problem with official measures of the capital stock is that they measure installed capital, not the portion of the capital stock actually in use.[5] Properly speaking, unemployed capital should not be counted in the production function, just as unemployed workers are not included in the measure of labour input. This becomes especially relevant for U.S.-Canada comparisons if the United States is closer to full capacity than Canada. If this is the case, then Canada's effective capital stock is over-estimated relative to that of the United States. However, as investment is quite cyclical, it may also be that investment rates are relatively lower in Canada than they would be in the long run, and so long-run capital intensity may be understated relative to the United States.

Conclusions

- The main conclusion to be drawn from this section is that in attempting to measure an investment gap in the context of the standard neoclassical growth model, one should focus on capital intensity and use the broadest possible measure of the capital stock.
- The importance of capital intensity differences in explaining productivity differences will be overstated in the long run if allowance is not made for the partial dependence of capital on technology.

A NEOCLASSICAL MODEL WITH CAPITAL-EMBODIED TECHNOLOGICAL CHANGE

A COMMON CRITICISM OF THE SIMPLE NEOCLASSICAL MODEL presented above is that growth can occur without any investment in new capital goods. However, as Solow (1960) famously argued, "Many, if not most innovations need to be embodied in new kinds of durable equipment before they can be made effective." If technological change manifests itself through the introduction of new capital goods, does that mean that we should be more concerned about any investment gap that might exist?

To model this idea formally, let's suppose that the stock of capital (K^*) is adjusted for quality as follows:

$$(7) \quad K_t^* = \int_{-\infty}^{t} e^{\lambda t} I(v)\,dv \ ,$$

where $I(v)$ is investment of a given vintage v, and λ is the rate of capital-embodied technological change — that is, the rate at which capital goods become more productive over time. Equation (8) shows the adjusted K^* in terms of the unadjusted gross capital stock, K:

$$(8) \quad K^* \cong K \cdot exp\left(\lambda - \lambda \cdot \overline{A}\right),$$

where $\overline{A}$ is the average age of the capital stock. This specification, introduced by Nelson (1964), indicates that older capital stocks will have a slower rate of technological change embodied in the adjusted capital stock. Using Equation (8), we can write the U.S.-Canada capital intensity gap as:

$$(9) \quad K_{US}^* / K_{Can}^* = (K_{US} / K_{Can}) exp\left\{\left(\lambda_{US} - \lambda_{Can}\right)\left(\lambda_{US}\overline{A}_{US} - \lambda_{Can}\overline{A}_{Can}\right)\right\}.$$

Hence, in the capital-embodied technological change model, a U.S.-Canada productivity gap could exist because of differences in disembodied TFP and the conventionally measured capital stock (as shown in Equation (2)). Now a productivity gap could also exist because of differences in the rate of capital-embodied technological change, and in the age of the capital stock. Note that, as in the basic model, capital is an endogenous variable that depends partly on the level of technology.[6] Equation (9) will therefore tend to overstate the long-run importance of capital accumulation in explaining productivity differences.

Issue: Interpreting Capital Stock Measures

A two-step procedure is required to arrive at a measure of the effective capital stock, K^*. First, investment needs to be scaled upwards by the rate of embodied technological change, λ; this corresponds to the term $exp(\lambda)$ in Equation (8). Second, the capital stock must be adjusted for the fact that embodied technological change renders older vintages of capital goods relatively less productive; this corresponds to the term $exp(-\lambda \cdot \overline{A})$ in Equation (8).

Statistical agencies in both the United States and Canada have now implemented both these steps. Statistics Canada and the Bureau of Economic Analysis now adjust their capital stock measures for quality change in certain investment goods, principally computers, using hedonic price indices.[7] By reducing the price of investment goods, the real stock of capital is essentially re-valued at the rate of technological change, λ. This corresponds to step one above. The second step is achieved by using these hedonic prices when calculating depreciation rates, which will reduce the value of older vintages of capital.[8] Thus, the net capital stock measures published by the two statistical agencies are, in principle, equivalent to the adjusted capital stocks, K^*.[9]

Issue: What is the Relevant Measure of Capital?

The use of effective capital stock measures allows us to distinguish between the proportion of the productivity gap that is due to disembodied technological change, and the proportion that is due to differences in effective capital per worker. However, from our perspective we are more concerned with separating the total contribution of embodied and disembodied technological change, both of which are invariant to the rate of investment in the neoclassical framework, from the contribution of capital accumulation.

Thus, what is required is a measure that approximates the theoretical quantity $K \cdot exp\left(-\lambda \cdot \overline{A}\right) = K^* / exp(\lambda)$, the portion of the effective capital stock that depends on the rate of investment. In order to implement this approach, a separate index of embodied technological change is required. One solution is to examine the quality-adjusted price of investment goods relative to consumption goods, which, as Greenwood et al. (1997) show, is a good proxy for the rate of capital-embodied technological change, λ.

Issue: Adjusting for Depreciation

As noted above, the net stock of capital should provide a good measure of the effective capital stock. However, if depreciation methods differ significantly across countries, then net capital stocks will not be comparable. Coulombe (2000) argues that such measurement differences do indeed exist between the

United States and Canada, and that they are significant, with depreciation rates being much higher in Canada. This would imply that the Canadian capital stock is underestimated relative to the U.S. capital stock. An alternative approach is to measure directly the age of the capital stock. If the average age of the capital stock is higher in one country, then this will indicate that the capital stock is less advanced and, therefore, less productive.

Conclusions

- The most appropriate measure of capital intensity in a neoclassical model with capital-embodied technological change is the effective net capital stock, adjusted to remove the pure impact of embodied technological change (as opposed to the interaction of capital-embodied technological change with the age of the capital stock).
- The degree of capital-embodied technological change can be proxied by the price of investment goods relative to consumer goods.
- Independent information on the age of the capital stock will also give a useful indication of the quality of the capital stock in situations where depreciation rates are not comparable.

ENDOGENOUS GROWTH MODELS

ENDOGENOUS GROWTH MODELS PROVIDE A PERSPECTIVE on the growth process that is quite different from the neoclassical model. As the name suggests, endogenous growth models attempt to explain all of the growth process as the result of the decisions made by optimizing agents, rather than leaving a portion of the growth process essentially unexplained, as in neoclassical models. This has important implications for how we think about the links between investment and productivity.

There is a wide variety of endogenous growth models: the main differences between them stem from whether it is physical capital, human capital or R&D spending that is the engine of growth. In this section, we survey examples of each of these three broad categories, which simply provide different mechanisms for determining A, either through physical capital, human capital or R&D.

Physical Capital-based Models

The canonical form of this class of endogenous growth models is due to Romer (1987). Output, Y, is given by the following production function:

$$(10)\quad Y = A \cdot L^{1-\alpha} \cdot \sum_{i=1}^{M} X_i^{\alpha},$$

where M is the number of different types of capital goods. Altering the number of capital goods involves a resource cost for firms. Each distinct type of capital good is produced according to a cost function:[10] $C(X_i) = c_0 + c_1 \cdot X_i$. The total amount of capital goods that can be produced at any point in time is limited by the amount of *primary* capital, Z, which is the amount of resources devoted to the production of capital goods. As the economy grows, the extent of specialization increases and new capital goods can be produced.

In equilibrium, the same amount of each kind of capital good will be produced. This gives:

$$(11)\quad X_i = \frac{K}{M},$$

where K is the unweighted sum of all X_is — the capital stock as conventionally defined. Substituting this expression into the production function of Equation (10) gives:

$$(12)\quad Y = A \cdot L^{1-\alpha} \cdot M \cdot K^{\alpha}.$$

The essential feature of Equation (12) is that while there is diminishing returns to the accumulation of a given kind of capital good, as in the standard neoclassical model, there is no such presumption for new types of capital goods. Thus, with M fixed, Equation (12) acts just like a standard neoclassical production function: the elasticity of output with respect to any of the M existing capital inputs is α. However, the elasticity of output with respect to an increase in M is unity. Thus, in this model, long-term growth comes from increases in the variety of new capital goods.

What are the implications of this model for the Canada-U.S. productivity gap? From Equation (10) we obtain:

$$(13)\quad \frac{y_{Can}}{y_{US}} = \frac{A_{Can}}{A_{US}} \cdot \left(\frac{k_{Can}}{k_{US}}\right)^{\alpha} \cdot \frac{M_{Can}}{M_{US}}.$$

Thus, it is the relative variety of capital M_{Can} / M_{US} in the two countries that is important, not simply the relative stock of capital.

One approach to measuring M_{Can} / M_{US} would be to use a measure of capital-embodied technological change. This is because increases in variety, which are what drive growth in this model, are embodied in new capital goods; they act to push out the production function in the same way as capital-embodied technological change. As explained in the previous section, one approach to measuring the quality of new capital goods is to compare the quality-adjusted price of new investment goods. If prices are falling faster in one country, this indicates that the quality of capital is growing more quickly.

Some researchers, such as De Long and Summers (1991), have used the investment share of machinery and equipment as a proxy for increases in capital quality, because machinery and equipment, and especially information technology, are thought to be the types of capital goods where new technologies are adopted most quickly. However, as Equation (13) makes clear, it is quite possible to have a greater volume of physical capital and yet have the same variety. What matters is the quality of investment, not its volume.

Human Capital-based Models

Physical capital is not the only possible engine of growth in endogenous growth models. Starting with Lucas (1988), a large amount of work has been done on models in which investment in human capital — both in education and on-the-job learning — leads to the generation of new ideas and, therefore, sustainable increases in TFP. A typical growth model incorporating human capital would take the form:

$$(14)\quad Y = A \cdot K^{\alpha} \cdot (h \cdot L)^{1-\alpha},$$

where h is average human capital per worker, a measure that would include years of schooling and years of relevant experience. As with the basic neoclassical model, physical capital accumulation is an endogenous variable in the long run, and so part of any long-run difference in physical capital intensity will be attributable to differences in human capital intensity.

R&D-based Models

In R&D-based models of economic growth, such as that of Romer (1990), investment in R&D is the main engine of growth. Unlike investment in physical capital, investments by firms in R&D do not face diminishing returns because new ideas and designs are non-rival, and so can be used by more than one person at a time at no additional resource cost. A simple growth model based on R&D might take the following form:

$$(15)\quad Y = A \cdot D^{\varepsilon+\delta} K^{\alpha} \cdot L^{1-\alpha-\varepsilon},$$

where D is the stock of R&D capital, ε is a parameter measuring the private returns to R&D, and δ is a parameter measuring the social returns over and above the private returns (i.e. spillovers). In this model, R&D is accumulated just like conventional physical capital, and its level is determined by the private rate of return that investors receive. With perfect competition, the share of national income accruing to owners of R&D capital will be equal to ε. However, private investment in R&D also generates spillovers, whose returns cannot be completely captured by the original investor.

When measuring the importance of R&D capital in a small open economy such as Canada's, it is important to allow for the possibility of spillovers from the R&D investment in other countries. Although the private returns to foreign R&D would not accrue to Canadians, there is no reason in principle why all the spillovers should stop at national borders.

Conclusions

- In endogenous growth models where physical capital is the engine of growth, the relative variety of capital goods is a key determinant of productivity. This variety will show up as an increase in the quality of the capital stock.
- In endogenous growth models where human capital is the engine of growth, a key determinant of productivity is the relative level of human capital per worker in each country.
- In endogenous growth models where R&D spending is the engine of growth, spillovers from investment in R&D, both domestic and foreign, are key determinants of productivity.

WHAT DO THE DATA SAY?

WE NOW EXAMINE THE EMPIRICAL EVIDENCE on a Canada-U.S. investment gap. As practitioners in this field will know, accurately measuring investment and the capital stock poses daunting methodological and empirical challenges. The difficulties are compounded when making cross-country comparisons. For this reason, we shall not try to quantify the precise contribution of investment to the productivity gap. Rather, we shall attempt to gain a qualitative sense of Canada-U.S. differences by examining a variety of measures of capital intensity, both stocks and flows.

PHYSICAL CAPITAL

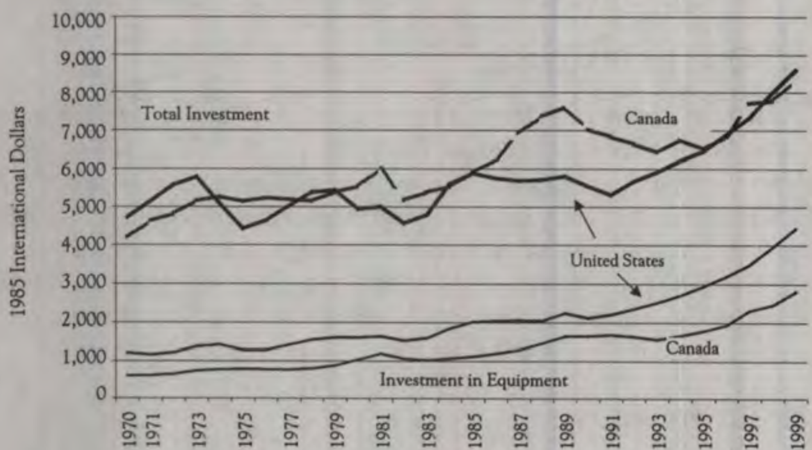
IDEALLY, MEASURES OF THE CAPITAL STOCK should be deflated by appropriate measures of prices. Statistical agencies in both the United States and Canada routinely publish such measures in constant-dollar terms, so that variables are measured in terms of the nominal value in an arbitrarily chosen base year. However, as McCabe (2000) points out, it is inappropriate to use such measures when comparing real investment ratios across countries. What is required is a measure that allows for inter-country comparisons of price levels. For this reason, we rely upon the Penn World Tables (Mark 5.6), which make precisely these kinds of adjustments. Because the data end in 1992, we have updated them using investment data from the OECD.

Investment and Capital Stock per Worker

Figure 1 illustrates net business sector investment per worker[11] in the United States and Canada, for all investments, and for investment in machinery and equipment. The data show that total investment per worker has been very similar in the two countries over the last thirty years, except for the period 1986-94 when investment levels were somewhat higher in Canada. This trend is confirmed by Figure 2, which shows that Canada's capital-labour ratio is currently very similar to that of the United States, after a period in the 1980s and early 1990s when it was higher in Canada than in the United States.

FIGURE 1

TOTAL INVESTMENT AND INVESTMENT IN EQUIPMENT PER WORKER, CANADA AND UNITED STATES, 1970-99



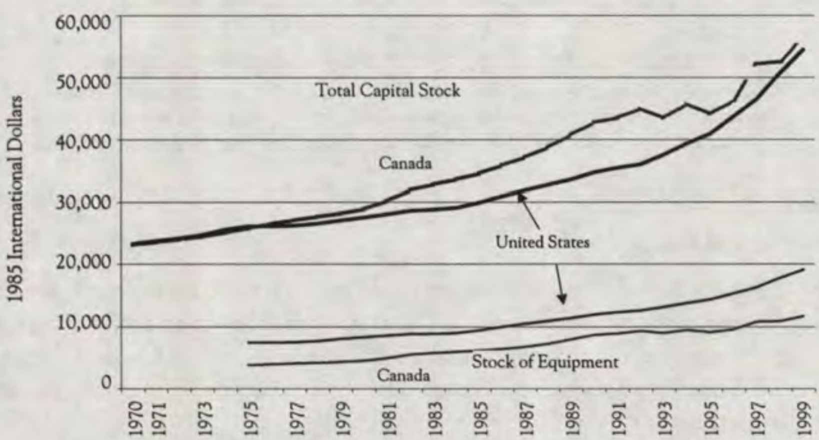
Source: Investment figures from Penn World Tables (1970-92, Mark 5.6a); employment data from *Comparative Civilian Labor Force Statistics, Ten Countries 1959-99*, Bureau of Labor Statistics (BLS) http://www.bls.gov/flswarn.htm; data updated using growth rates from real investment figures published in the *Quarterly National Accounts*, Vol. 2, OECD, 2000, and employment data from the BLS.

The picture changes when we narrow the focus to machinery and equipment. Investment in this type of capital is more than 50 percent greater in the United States than in Canada. Furthermore, the gap is of long standing, as demonstrated by Figure 2, which reveals a significantly lower stock of machinery and equipment per worker in Canada. This trend is confirmed by Figure 3, which shows that the computer capital stock per worker in the United States almost doubled between 1996 and 1998, whereas in Canada it only increased by 50 percent.[12]

Kirova and Lipsey (1998) go further than us in broadening the definition of the capital stock by including expenditures on consumer durables, education, defence and R&D. They find that with this broader definition, Canada's investment share of GDP is somewhat higher than that of the United States.

FIGURE 2

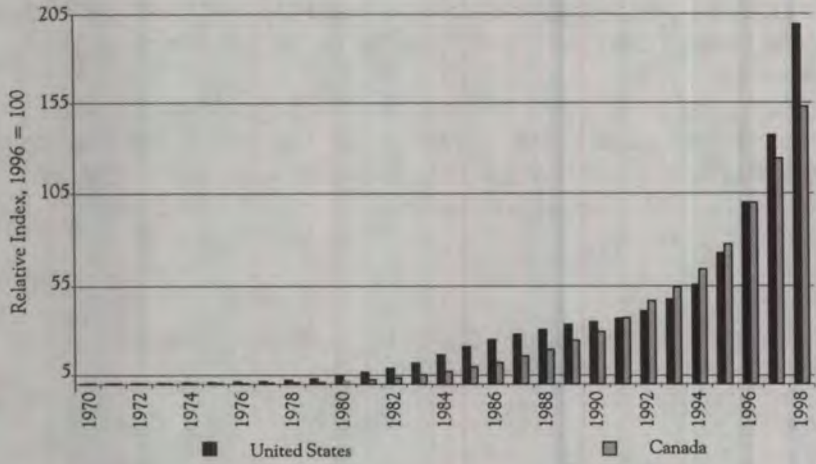
TOTAL CAPITAL STOCK AND STOCK OF EQUIPMENT PER WORKER, CANADA AND UNITED STATES, 1970-99



Source: Capital stock per worker and producers durables (equipment) from Penn World Tables (1970-92, Mark 5.6a). Capital stock figures updated using growth rates from real investment figures published in *Quarterly National Accounts*, Vol. 2, OECD, 2000, and employment data from *Comparative Civilian Labor Force Statistics, Ten Countries 1959-99*, Bureau of Labor Statistics, http://www.bls.gov/flswarn.htm.

FIGURE 3

STOCK OF COMPUTERS PER WORKER, CANADA AND UNITED STATES, 1970-98



Source: Estimates of capital stock (computers) from Bureau of Economic Analysis (U.S. data) and Statistics Canada (Canadian data). Comparable employment data from *Comparative Civilian Labor Force Statistics, Ten Countries 1959-99*, Bureau of Labor Statistics, http:/www.bls.gov/flswarn.htm.

Age of Capital Stock

Table 1 contains data on the average age of the capital stock, for both machinery and equipment, and total investment. The data show that over the last twenty years, the average age of the total capital stock has been lower in Canada than in the United States, although the average age of the machinery and equipment stock has been quite similar.

Price Indices

Figure 4 shows the implicit price index for investment goods in the United States and Canada relative to the price of consumption goods. The data are taken from the OECD Quarterly National Accounts and are intended to be as comparable as possible. Price movements were quite similar in Canada and the United States over the 1990s, with significant declines driven in part by hedonic adjustments designed to capture quality changes in new capital goods.

TABLE 1

AVERAGE AGE OF CAPITAL STOCK (EQUIPMENT AND TOTAL), UNITED STATES AND CANADA, 1961-97

	UNITED STATES		CANADA	
	EQUIPMENT	TOTAL	EQUIPMENT	TOTAL
		NUMBER OF YEARS		
1961-73	6.8	17.3	8.0*	13.8
1974-79	6.6	16.0	7.3*	13.1
1980-89	6.9	15.4	7.0*	13.2
1990-94	7.3	15.7	7.0	13.9
1995-97	7.2	16.1	7.1	14.3
		ANNUALIZED GROWTH RATES (%)		
1961-73	-1.0	-1.0	-0.7	-0.8
1974-79	0.3	-0.4	-1.1	-0.1
1980-89	0.7	0.0	0.1	0.4
1990-94	0.3	0.9	0.6	0.9
1995-97	-0.9	0.0	-0.5	0.0

Note: * Before 1984, the average service life in Canada was not based on a regular survey, and these data should be treated with caution.

Source: For Canada, *Fixed Capital Flows and Stocks 1961-1994*, Statistics Canada, Cat. No. 13-568, Section IV, p. 60. Updated to 1999 by Statistics Canada on request. For the United States, *Fixed Reproducible Tangible Wealth in the U.S.*, August 1999, U.S. Department of Commerce, Table 1.1, 1995-97 figures are preliminary.

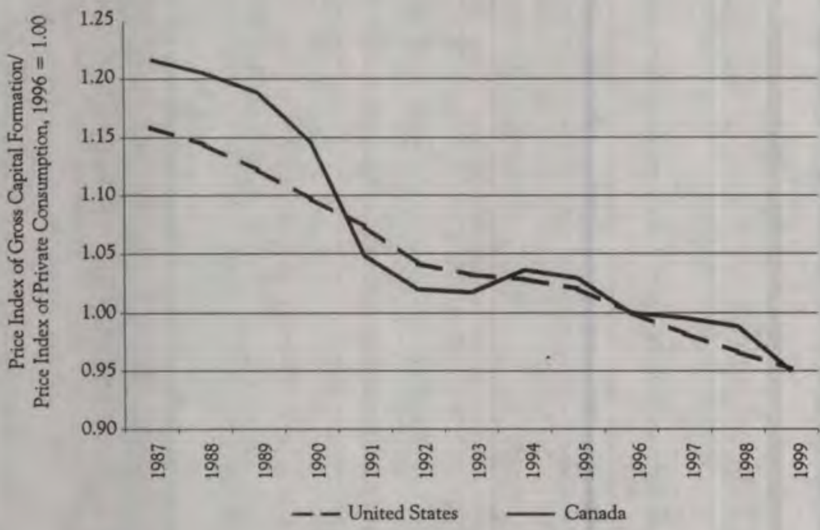
It may seem strange that the fall in the relative price of investment goods is similar in both countries, given that machinery and equipment represents a significantly larger share of investment spending in the United States. The explanation is quite simple: it appears that the relative price of machinery and equipment has fallen more rapidly in Canada than in the United States. According to the IMF (2000, p. 5), the rate of capital-embodied technological change was one percentage point higher in Canada than in the United States over the period 1988-97.

HUMAN CAPITAL

THE MOST COMMON APPROACH to measuring differences in the level of human capital per worker is to use quantity measures such as the average completed years of schooling, or the proportion of the population with higher education. By these measures, the average level of human capital in Canada is very slightly below that in the United States. The average number of completed years of schooling is 13 in the United States compared to 12 in Canada, and the

FIGURE 4

RELATIVE PRICE OF GROSS CAPITAL FORMATION VERSUS PRIVATE CONSUMPTION, CANADA AND UNITED STATES, 1987-99



Source: *Quarterly National Accounts*, Vol. 2, Table 2, OECD, 2000.

proportion of the population aged 25 and over with higher education is 48 percent in the United States compared to 45 percent in Canada.[13] Growth rates of these variables over the last ten years are roughly comparable.

The advantage of these quantity measures is that they are easily available. However, from a theoretical perspective, simply adding up years of schooling is problematic because an additional year of high school probably has a different impact (marginal benefit) on productivity than an additional year of graduate school. What is required to construct a proper measure of the human capital stock is a way of weighting the different components of that stock by their respective marginal productivity. A common approach to this problem is to use information from wage rates in order to estimate the marginal product of each year of schooling, which is not a bad approximation as long as educational wage differentials largely reflect differences in acquired human capital and not innate individual ability.[14] The marginal productivity estimates are then combined with quantity information to produce a measure of the human capital stock.

Table 2 reports estimates of the human capital stock from two studies: Sala-i-Martin and Mulligan (1994) for the United States, and Laroche and Mérette (2000) for Canada. Both measures grow at roughly comparable rates over the period 1977-89. After 1990, the growth rate of the Canadian measure slows considerably. Although there is no data for the U.S. measure after 1990, the fall in the growth rate of average years of schooling would suggest a similar slowdown in the growth rate of the U.S. human capital stock.

R&D CAPITAL

TABLE 3 SHOWS VARIOUS ESTIMATES of the stocks and flows of R&D capital in Canada and the United States. It is clear from these data that Canada lags considerably behind the United States. The number of researchers relative to the labour force is significantly higher in the United States (74 per 10,000 compared to 54 per 10,000 in Canada), and domestic expenditure on R&D is 2.8 percent of GDP in the United States compared to 1.6 percent in Canada. There is some indication that Canada is gradually narrowing the gap in terms of researchers, but this is not true for R&D expenditures.

One point to bear in mind is that these figures relate to the production of R&D, not to the total stock available to the average Canadian worker. As noted in the first section, if the results of R&D can spill over national borders, then the stock of R&D in Canada will be greater than the domestic production figures would suggest. The presence of many U.S. multinational companies in Canada would be an obvious channel for the importation of U.S. R&D output into Canada. Some evidence on this aspect is presented in Bernstein and Mamuneas (2000), who find that there are indeed significant spillovers to Canada from R&D performed in the United States.

Finally, international trade is another channel through which Canada can benefit from U.S. R&D. Canadian firms can easily purchase investment goods as technologically advanced as those used by their American counterparts.

SUMMARY

AS WE NOTED AT THE OUTSET, any comparison of capital stock data for the United States and Canada must be interpreted with great caution. Nevertheless, several broad patterns do emerge, and we feel there is sufficient evidence to support the following conclusions:

- There is little evidence of a significant gap between the United States and Canada in the overall level of physical capital per worker;

TABLE 2

HUMAN CAPITAL STOCK: NUMBER OF UNIVERSITY-EDUCATED PEOPLE OVER 25 YEARS OLD AND AVERAGE YEARS OF SCHOOLING, UNITED STATES AND CANADA, 1976-98

	UNITED STATES			CANADA		
	PEOPLE WITH HIGHER EDUCATION (% OF POPULATION 25+)	AVERAGE YEARS OF COMPLETED SCHOOLING	HUMAN CAPITAL STOCK* (LOG)	PEOPLE WITH HIGHER EDUCATION (% OF POPULATION 25+)	AVERAGE YEARS OF COMPLETED SCHOOLING	HUMAN CAPITAL STOCK* (INDEX 1976=100)
1976-79	29.4	12	0.4208	21.0 *****	11	107
1980-89	35.1	12	0.4991	25.3 *****	11	122
1990-94	42.8	13	0.5481	39.5	12	130
1995-98	48.3	13		45.8	12	133 **
			ANNUALIZED GROWTH RATES (%)			
1977-79	1.3	0.5	0.9 ***	0.2 *****	0.3	3.0
1980-89	3.8	0.5	1.6 ****	3.2 *****	0.5	1.0
1990-94	2.1	0.5		3.4	0.5	0.5
1995-98	3.8	0.2		2.6	0.4	0.2 **

Notes: * Labour-income-based measure of human capital. For the United States, Sala-i-Martin and Mulligan (1994); for Canada, Laroche and Mérette (2000).
** 1995-96 only.
*** 1970-80.
**** 1980-90.
***** Canadian data before 1990 are not strictly comparable to post-1990 data.
American data taken from http://www.census.gov/population/socdemo/education/tableA-1.txt. Canadian data from Labour Force Survey by educational attainment, special tabulation.

Source: U.S. Census Bureau; Statistics Canada; Sala-i-Martin and Mulligan (1994); and Laroche and Mérette (2000).

TABLE 3

INDICATORS OF R&D CAPITAL STOCK, UNITED STATES AND CANADA, 1970-99

	UNITED STATES			CANADA	
	BEA ESTIMATES (1987$ BILLIONS)*	ESTIMATES BASED ON R&D EXPENDITURES (1996$ BILLIONS)**	NUMBER OF RESEARCHERS (PER 10,000 LABOUR FORCE)***	ESTIMATES BASED ON R&D EXPENDITURES (1992$ BILLIONS)**	NUMBER OF RESEARCHERS (PER 10,000 LABOUR FORCE)***
1970	581	N/A	N/A	N/A	N/A
1975	646	63.2	N/A	2.9	N/A
1980	686	163.6	62 (1981)	8.4	31 (1981)
1985	797	391.4	68	22.9	40
1990	978	674.8	75****	41.7	45****
1995	N/A	972.3	74 (1993)	59.6	54
1999	N/A	1,387.9	N/A	78.5	N/A
			ANNUAL AVERAGE GROWTH RATES (%)		
1970-75	1.8	N/A	N/A	N/A	N/A
1975-80	1.0	17.2	N/A	19.3	N/A
1980-85	2.5	15.7	5.3	18.3	5.3
1985-90	3.5	9.5	3.6	10.5	4.8
1990-95	N/A	6.3	0.2	6.2	5.1
1995-99	N/A	7.4	N/A	5.6	4.2 (1995-98)

Notes:
* BEA estimates of R&D net total capital stock taken from http://www.bea.doc.gov/bea/an/1194od/boxtab.htm.
** Own calculations using annual expenditures on R&D starting in 1970 and a 11-percent rate of depreciation.
*** OECD, *Science, Technology and Industry Scoreboard*, 1999, Table 3.1.
**** Extrapolated from 1989 and 1991 OECD figutes.

Source: U.S. Bureau of Economic Analysis; OECD; and authors' calculations.

- However, there is robust evidence that the proportion of machinery and equipment in the capital stock is significantly higher in the United States than in Canada;
- Canada's capital stock does not appear to be older than that of the United States, nor do the data suggest that capital quality is increasing faster in the United States than in Canada;
- There is no evidence of a significant gap between the United States and Canada in the level of human capital per worker; and
- There is a large gap between the United States and Canada in the production of R&D, although this may be somewhat attenuated by spillovers from the United States into Canada.

CONCLUSIONS

WE SHALL NOW ASSESS THE EMPIRICAL EVIDENCE presented above in the context of the growth models described in the first section. In each case, we would like to know whether the Canada-U.S. investment gaps that we have identified could cause a gap in labour productivity between the two countries.

BASIC NEOCLASSICAL MODEL

AS WE HAVE SEEN, the relevant measure of capital for the basic neoclassical model is the broadest possible measure of the physical capital stock, possibly augmented by the stock of human capital. In either case, there is little evidence that differences in capital per worker can explain more than a small fraction of the Canada-U.S. productivity gap. Instead, differences in technology, industrial structure or other similar factors must take the blame. This conclusion is all the more true in the long run, because, as noted in the first section, some part of any difference in capital intensity is ultimately the result of differences in these other factors.

NEOCLASSICAL MODEL WITH CAPITAL-EMBODIED TECHNOLOGICAL CHANGE

IN THIS MODEL, THE RELEVANT VARIABLES are the size of the capital stock, as before, and the age of the capital stock. The capital stock of more recent vintage is more technologically advanced, and therefore more effective. However, as far as we can tell, there is little difference in the average age of the capital stock between Canada and the United States. Furthermore, the rate of capital-embodied technological change appears similar in the two countries; consequently, adjusting the capital stock for the rate of capital-embodied technological change in order to net out increases in the effective capital stock that are unrelated to investment will not change the fact that overall capital intensity appears similar in the two countries.

ENDOGENOUS GROWTH MODELS

IN ENDOGENOUS GROWTH MODELS where physical capital is the engine of growth, as in neoclassical models with capital-embodied technological change, the quality of capital is an essential component of the growth process. The difference with the neoclassical model is that capital quality is endogenous rather than exogenous. What evidence is there that Canada's capital stock lags behind that of the United States in quality? It is undeniable that a greater share of the U.S. capital stock is made up of machinery and equipment. On the other hand, as noted above, data on the average age of the capital stock and changes in the price of capital tend to suggest that there is little difference in overall capital quality between Canada and the United States, in part because quality change in machinery and equipment seems to be proceeding somewhat faster in Canada than in the United States.

Because the level of human capital is similar in both countries, endogenous growth models based on human capital would clearly not point to a human capital investment gap as the cause of differing productivity levels.

However, models in which R&D is the engine of growth could point to an investment gap as the main cause of the Canada-U.S. productivity gap, even allowing for some spillovers of U.S. R&D into Canada. Here, the issue is one of magnitude. Table 3 provides information on the size of the U.S. R&D capital stock up to 1990 (a similar argument could be made for Canada).[15] The U.S. figure for 1990 is approximately US$1 trillion in 1987 dollars. Large though this figure seems, it is dwarfed by the size of the total U.S. physical capital stock, which was around US$17 trillion in 1990.

Assuming that the private rates of return on R&D are of a similar magnitude to the rates of return on other types of capital would imply that the share of R&D in national income is much smaller than that of physical capital — around 2 to 3 percent based on the figures presented above. This proportion is too small for a Canada-U.S. R&D capital stock gap to have much impact on productivity differences simply through its effect on the private gains from R&D expenditures.

Thus, if differences in the R&D capital stock are to affect productivity it must be through the spillover effect — that portion of the gains not captured by the firm incurring the expenditure. Furthermore, the magnitude of this spillover effect must be very large in order to explain most of the gap. If Canada's R&D stock is about half that of the United States (as suggested by data on investment flows), then the spillover parameter, δ, would have to be around 0.3 — ten times the private returns parameter, ε — in order to explain a Canada-U.S. productivity gap of 18 percent. The spillover parameter would have to be even larger if Canada benefits from some U.S. R&D spillovers.

OVERALL CONCLUSIONS

WE FIND THAT CANADA SIGNIFICANTLY UNDERINVESTS by comparison with the United States in R&D and in machinery and equipment. This conclusion confirms that of other researchers. However, we differ in the significance that we ascribe to these results. In particular, we do not agree that these investment gaps necessarily explain much of the Canada-U.S. productivity gap.

- For the R&D gap to be the main contributor to the productivity gap, two conditions must hold: first, the social returns must be of an order of magnitude greater than the private returns; and second, a large proportion of the spillovers must stop at the national border.
- For the machinery and equipment gap to be the main contributor to the productivity gap, this gap must measure more accurately existing differences in capital quality than the other measures we examined.

In both cases it seems to us that the case is not proven.

This is not to say that differences in capital quality and innovation do not contribute to the productivity gap. Clearly, something must explain the gap, and that explanation may be related to under-investment of some kind. However, the gap does not seem to be the result of under-investment at the level of the broad aggregates examined here. This has important implications for policy, because it means that policy measures — such as taxes and subsidies — that target these broad aggregates may not be the most efficient means of affecting the underlying causes of the productivity gap.

ENDNOTES

1 We are abstracting from factors such as depreciation and changes in the relative price of capital goods that would cause the rental price of capital to deviate from the real rate of interest.
2 See Hall and Jones (1999), and Bassanini et al. (2000).
3 Kirova and Lipsey (1998) follow this approach.
4 In equilibrium, the marginal product of each type of capital should equal its own marginal cost, estimated by rental or user costs, which varies by asset type because of differences in taxes, depreciation and changes in acquisition prices.

5 Basu (1996) exploits the intuition that material inputs do not have variable utilization rates, and materials are likely to be used in fixed proportions with value added, so that growth in materials becomes a good measure of unobserved changes in capital and labour utilization.

6 See the discussion in Hulten (1979).

7 The use of hedonic prices to measure increasing quality in capital goods raises some difficult issues in the measurement of output, as emphasized by Greenwood et al. (1997) and Hercowitz (1998). Their argument is that such measures should not be used to calculate national income, as opposed to capital stock measures, and that the correct measure of I in the formula $Y=C+I+G+NX$ is investment in consumption units. Incorporating capital-embodied technological change in capital goods prices will mean that the price of investment goods will fall indefinitely relative to the price of consumption goods, and so I will be progressively overstated in real (consumption unit) terms. At the limit, the ratio of quality-adjusted investment to national income will go to one (Greenwood et al. 1997, p. 356). Although period re-basing of the national accounts will prevent this from actually occurring, it is nonetheless true that quality-adjusted investment shares will become progressively larger over any given time period. In a world of chain-weighted series, ratios of real series start losing some of their original meaning. While investment shares should then be calculated in nominal terms to avoid the problem, it may also be reasonable to avoid the use of investment shares altogether as a measure of capital accumulation whenever possible.

8 Nelson (1964) shows that adjusting the capital stock for economic as well as physical depreciation is equivalent to adjusting for the age of the capital stock. This is because the impact of capital-embodied technological change on the existing capital stock is precisely the process of economic depreciation described above: as newer, better, capital goods become available, the replacement cost of existing capital goods drops, and so does their economic value. This process is independent of the fact that existing capital goods may be physically less productive.

9 See, however, Whelan (2000), who argues that current depreciation methods overstate depreciation rates when prices are adjusted for quality change.

10 This slightly simplified version of the cost function in the Romer model is taken from Aziz (1996).

11 In these data, software is not counted as investment for either country.

12 Computer capital stock data for Canada are preliminary unpublished Statistics Canada data.

13 Although we should caution the reader that the definitions of higher education in the two countries are not entirely comparable.

14 Human capital is sometimes partly reflected in labour inputs. A large segment of the growth accounting literature includes estimates of labour quality by weighting heterogeneous labour inputs. For instance, the Bureau of Labor Statistics measures labour inputs for the purpose of total factor productivity by estimating an aggregate measure of hours of work by type of worker. The growth rate of that aggregate is therefore an average of the growth rates of each type of worker weighted by its share of total labour compensation. The resulting aggregate measure of labour inputs accounts for both the increase in gross hours at work and changes

in the skill composition (as measured by education and work experience) of the labour force. See Bureau of Labor Statistics (1997) for details.

15 These U.S. figures are from the Bureau of Economic Analysis. Statistics Canada does not produce comparable figures for Canada. Table 3 shows our own comparable stock estimates based on R&D expenditures for the United States and Canada.

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Part IV
Global Linkages and Productivity

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15

Foreign Investment, Trade and Industrial Performance: Review of Recent Literature

INTRODUCTION

CANADA HAS TREMENDOUS EXPOSURE to the international marketplace. Foreign-controlled firms account for half of manufacturing sales in Canada, while roughly 40 percent of the country's GDP is exported. Recent Canadian policies have removed impediments to both inward investment and imports. The 1988 Canada-U.S. Free Trade Agreement (FTA) eliminated tariffs with Canada's dominant trading partner. The dismantling of Canada's *Foreign Investment Review Act* in 1984 signalled a commitment to an open policy towards investment that was augmented by investment protection provisions in the FTA.

The two studies presented in this section take stock of the policies that have facilitated Canada's integration into the world economy. *A Time to Sow, a Time to Reap: The FTA and its Impact on Productivity and Employment*, by Gary Sawchuk and Daniel Trefler, relates changes in various aspects of manufacturing performance, including output, employment and productivity, to tariff changes mandated by the FTA. Their results suggest both long-term benefits and short-term pain from the Agreement. In *Are Canadian-Controlled Manufacturing Firms Less Productive Than Their Foreign-Controlled Counterparts?*, Someshwar Rao and Jianmin Tang measure the difference in multi-factor productivity between foreign- and domestically controlled firms in Canada and investigate the source of the difference. The results of their study have implications regarding the welfare effects of open policies towards investment.

In this review, we will discuss the details of these studies in the context of the large literature on trade and investment liberalization. We will describe theoretical models that predict outcomes consistent with their results. We will also discuss how these authors employ data and techniques that advance the empirical work in this area. The review begins with a discussion of Sawchuk and Trefler's study in relation to the trade literature. It then proceeds with a discussion of Rao and Tang's analysis in the context of the foreign direct investment (FDI) literature. The final section summarizes the two studies and their policy implications, and it identifies areas of future research.

EFFECTS OF TRADE LIBERALIZATION

THE STUDY ENTITLED *A Time to Sow, a Time to Reap: The FTA and its Impact on Productivity and Employment*, by Gary Sawchuk and Daniel Trefler, investigates the effects of the tariff reductions implemented within 213 4-digit SIC industries in Canada. The authors relate tariff reductions to changes in employment, output, the number of establishments, trade, and labour productivity. As stated in their summary, they find that FTA tariff cuts resulted in:

- A reduction in manufacturing employment, output and the number of establishments: For industries experiencing tariff cuts exceeding 8 percent (impacted industries), the reductions are estimated to be at least 12 percent. For manufacturing as a whole, the declines are fairly modest, i.e. around 5 percent.
- An increase in labour productivity: 3.2 percent per year for highly impacted industries, and 0.6 percent per year for all manufacturing.
- An increase in the annual earnings of production workers: Tariff cuts raised production workers' earnings by 0.8 percent but did not appear to affect non-production workers' earnings.
- Increased trade with the United States: Tariff cuts explain almost all of the increase in trade with the United States in impacted industries. However, industries where trade grew the most were not subjected to tariffs in the United States in 1988.

Sawchuk and Trefler's study is strictly empirical and the authors do not discuss their results in a theoretical context. In what follows, we first explain how the techniques they employ isolate the effects of FTA tariff reductions and contribute to the empirical literature on the FTA. We then provide a survey of the relevant trade literature and discuss their results in light of the theory.

The authors articulate the various problems associated with inferring FTA effects from aggregate data and time-series evidence. Foremost are the difficulties in determining that the FTA was the source of observed changes in manufacturing activity. Monetary policy, movements in the business cycle, and exchange rate fluctuations are confounding factors that may underlie changes in Canadian manufacturing. To identify FTA effects, researchers must link differences in the degree to which industries are liberalized under the FTA to the variation in industry performance.

Sawchuk and Trefler point out how the use of aggregate data imposes severe limitations in identifying FTA effects. First, while tariff cuts may be substantial for the specific products to which they are applied, they will show much less variation when averaged across the large number of products found within a 2-digit industry. The authors show that almost 30 percent of 4-digit industries had tariffs against the United States of 10 percent or more in 1988. If the data are aggregated at the 3-digit level, almost no industries had a 10-percent tariff protection. Thus, the large variation in tariff reductions across 4-digit industries is largely obscured in more aggregated data.

A second problem with aggregated data is that the experience of large industries will be the driving force of variation in manufacturing performance within particular 2-digit industries. For example, the Motor Vehicle industry is part of the 2-digit Transportation industry and accounts for 40 percent of manufacturing output. This industry enjoyed free trade with the United States prior to the FTA and observed changes in its performance should not be attributed to that agreement.

One valuable aspect of Sawchuk and Trefler's study is that it identifies FTA effects using the variation in tariff changes that occurred within 213 4-digit industries. Another contribution from these authors is their approach to differencing the data in order to control for secular, business-cycle, and industry effects. First, they calculate an approximation of the annual compound growth rate of the variables of interest — output, employment, productivity, etc. — for each of two periods: the post-FTA period and the pre-FTA period. Sawchuk and Trefler explain that these two periods were quite similar in terms of the business cycle. They then relate the differences in growth rates between the two periods to FTA tariff cuts. Their differencing technique eliminates business-cycle and industry-specific effects that may confound the analysis.[1]

As previously mentioned, Sawchuk and Trefler do not position their results in a theoretical context. Their purpose is not to test theory but to provide a thorough accounting of FTA effects. However, as we will explain, their decision to focus only on changes occurring within 4-digit industries restricts the scope of the effects they are able to identify. Therefore, the following survey of theory serves two purposes. First, it complements Sawchuk and Trefler's empirical analysis by providing a theoretical backdrop that is useful for interpreting results. Second, it identifies FTA effects that may not be detected in their analysis.

THEORIES OF TRADE LIBERALIZATION AND INDUSTRY PERFORMANCE

THIS SECTION BEGINS WITH A BRIEF DESCRIPTION of traditional trade theory and discusses why it is unlikely to explain the results presented in Sawchuk and Trefler's study. It then outlines a number of *new trade* theories that provide a better framework for Sawchuk and Trefler's analysis. These authors investigate the effects of tariff reductions on a large number of industry performance measures, including employment, earnings, output, trade, and labour productivity. We will confine our discussion to predictions made by the theory about the effects of trade liberalization on output and productivity.

The Ricardian model and the Heckscher-Ohlin theorem predict the expansion and contraction of specific industries in response to trade liberalization. The simple Ricardian model argues that differences across industries and nations in labour productivity determine the patterns of trade. Nations will export goods of industries for which they have a comparative advantage in production. The Heckscher-Ohlin theorem states that a country has a comparative advantage in goods that are intensive in the country's relatively abundant factors. Again, countries will export goods for which they have a comparative advantage. These traditional models predict that the effects of trade liberalization on output will depend on comparative advantages: there will be a rise in the output of goods for which a country has a comparative advantage, and a fall in the output of goods for which it has a comparative disadvantage. Resources will move from comparatively disadvantaged industries towards those that have a comparative advantage. A central prediction of traditional trade theory is the inter-industry reallocation of resources.

It may be that the United States or Canada enjoys a comparative advantage across all goods within the manufacturing sector or that their comparative advantage varies across goods within manufacturing. If one country has a uniform advantage in the production of manufactures, then trade liberalization will either harm or hurt it in terms of output. However, if the comparative advantage varies within manufacturing, the effects of trade liberalization will be heterogeneous, depending both on the size of the tariff reduction and on the comparative advantage.

What implications does traditional trade theory have for the estimation strategy adopted in Sawchuk and Trefler's study? If tariff reductions raise output in some industries and lower it in others within the manufacturing sector, estimating a single tariff effect is incorrect. Instead, the effect should be allowed to vary according to the comparative advantage. Researchers would have to relate the tariff variable with another variable indicating whether liberalization is harmful or beneficial to a particular industry.

Another feature of traditional trade theory is that, while it predicts higher aggregate productivity as a result of trade liberalization, it does not predict higher productivity within industries. Aggregate productivity gains occur when resources are reallocated to industries that have a comparative advantage and away from industries that have a comparative disadvantage. Industry-level productivity gains need not occur.

We will now explain why Sawchuk and Trefler's specification, while inconsistent with traditional trade theory, is adequate for modelling Canada-U.S. trade. First, traditional trade theory predicts that goods will be traded in a single direction and countries should not export and import the same goods. However, two-way trade characterizes North American manufacturing. The Grubel-Lloyd intra-industry trade index is calculated as two times the minimum of imports or exports divided by the sum of imports and exports. Thus, it equals zero for one-way trade, and one when imports and exports are equal. Head and Ries (1997) show that this index for Canada-U.S. bilateral trade in 1987 exceeds 0.50 in 15 out of 22 2-digit industries. Aside from one-way trade not characterizing Canada-U.S. trade, there is scant evidence that shifts in resources across industries account for changes in industry performance as traditional trade theory predicts. Davis and Haltiwanger (1999) report that less than 1 in 10 job reallocations reflect employment shifts across manufacturing industries.

In what follows, we describe a number of new trade models that could give rise to the within-industry changes found by Sawchuk and Trefler. Generally speaking, what distinguishes new trade models from traditional trade models is the fact that they incorporate imperfect competition and increasing returns to scale. The first new trade model we discuss is attributable to Krugman (1980) and contains the *home market effect*, which implies that tariff reductions increase manufacturing production in the larger country. However, this theory does not predict productivity changes. The Eastman-Stykolt hypothesis foresees that tariff reductions will improve productivity by forcing firms to increase their scale of operations. Next, we describe a very recent model of industries with heterogeneous firms, developed in Melitz (1999), where liberalization increases industry-level production by forcing inefficient firms out of the market. Finally, we discuss the trade and growth literature that explicitly models the relationship between total factor productivity growth and trade.[2]

The Home-market Effect

A key insight of the monopolistic competition model developed in Krugman (1980) is that size confers an advantage: firms find it attractive to locate in the country with the greatest number of consumers. An industry that hosts a disproportionate amount of firms due to its size advantage will run a trade surplus that is magnified by trade liberalization. Head and Ries (1999a) motivate their empirical analysis of the effects of FTA tariff reductions based on the Krugman model's prediction of the effects of trade liberalization on unequally sized trading partners.

Krugman's model depicts manufacturing as characterized by increasing returns to scale, differentiated products and free entry. Manufacturing firms are assumed to produce each a unique variety, and consumers wish to purchase each variety. The central prediction of the model is that the country with the relatively larger share of demand will host a majority of firms and run a trade surplus in the monopolistic competition sector.[3] Trade is balanced by a constant-returns-to-scale sector (agriculture). Weder (1995) adapts this model to allow for balanced trade across monopolistic-competitive industries. He shows that the country with a relatively larger share of demand will be a net exporter.

Krugman's model predicts that Canadian manufacturing will contract under the FTA. With roughly 10 percent of North American demand, Canada would experience an exodus of firms due to trade liberalization. However, the adaptation of this model by Weder generates heterogeneous effects across manufacturing industries — manufacturing industries in Canada that are large relative to the Canadian average will see their net exports increase, whereas small manufacturing industries will shrink. The effects of trade liberalization would not be uniform; growth or contraction would depend on whether the industry has a relative *demand* advantage. Sawchuk and Trefler's result linking the FTA tariff cuts with reduced Canadian manufacturing output may be viewed as being broadly consistent with the initial formulation of Krugman's model.

While there are increasing returns to scale in the Krugman model that potentially admits increased productivity through increased scale, one undesirable feature of the model is that trade liberalization does not influence the scale of operations, only the number of firms. Therefore, it cannot account for the productivity increases detected by Sawchuk and Trefler. Krugman (1979) formulates a more general specification of imperfect competition and differentiated goods, and shows that trade liberalization causes firms to move down along their average cost curve. We now turn to other models where tariff reductions increase productivity within industries: tariff limit pricing, Melitz's model of heterogeneous firms, and the trade and growth models.

Tariff Limit Pricing

The Eastman-Stykolt hypothesis contends that tariff protection has allowed Canadian firms to maintain high prices, and thereby contributed to excess entry in Canadian industries.[4] Thus, before trade liberalization, the Canadian manufacturing sector had too many firms operating at sub-optimal output levels, a characterization that is consistent with the data. The logic of the argument is that as tariffs fell, concomitant price reductions would force exit and allow remaining firms to expand output and realize greater economies of scale.

Trade liberalization and tariff limit pricing can produce some of the results obtained by Sawchuk and Trefler. Average industry productivity would increase with the reduction in tariff protection, the larger improvements being experienced by industries where tariffs fall the most. A criticism of the tariff limit-pricing model, however, is that prices are set to exclude imports. Thus, the model is inconsistent with two-way trade. A very recent model of trade allows for two-way trade while explicitly addressing firm-level heterogeneity within industries.

Trade Liberalization and Heterogeneous Firms

Melitz (1999) augments the Krugman monopolistic competition model to allow for the presence of heterogeneous firms. He assumes that firms make irreversible investments to enter an industry, which leads to the co-existence of firms with heterogeneous productivity levels in equilibrium. He considers that exporters pay a one-time fixed cost to sell abroad. Only the most productive firms are willing to pay this cost in order to secure the revenues from exports sales. Trade liberalization, modelled as a reduction in the fixed cost of entering the export market, causes additional foreign and domestic firms to pay the exporting cost and sell abroad. The concomitant increase in competition from imports forces the exit of relatively unproductive firms that only sell locally. Thus, the model predicts that the effect of trade liberalization will be heterogeneous — beneficial to productive firms but harmful to unproductive ones. Individual industries realize productivity gains as a result of the exit of relatively inefficient firms and the expansion of efficient ones.

Trade and Growth

Traditional trade theory viewed technology as a basis for trade. The early work of Ricardo demonstrated the patterns and gains of trade in terms of productivity differences across countries. In Ricardo's model, trade gives rise to an aggregate static productivity gain as countries restructure production towards relatively productive activities. More recent theory incorporating increasing returns and imperfect competition reverses the direction of causality — trade can generate sustained technological progress and productivity growth.

Industry productivity in the Ricardian model is exogenous. Thus, this model cannot account for the productivity growth occurring within industries detected by Sawchuk and Trefler. The literature on trade and growth focuses on how productivity growth is influenced by trade. As described in the survey article of Grossman and Helpman (1995) — two leading contributors to this area of research — there are two primary types of technological progress modelled in this literature. First, progress created from learning-by-doing as a by-product of production activities. Trade enhances productivity growth when it increases output and thereby accelerates knowledge creation. A second class of models views technological progress as a result of deliberate attempts by firms to create knowledge.

Grossman and Helpman explain how learning-by-doing generates productivity gains that are enhanced when knowledge spills across firm boundaries and national borders. They discuss models that incorporate traditional trade theory's assumption of perfect competition and predict that trade may either accelerate or decelerate productivity and output growth. These models do not seem appropriate for depicting the effects of the FTA on Canadian manufacturing because they describe one-way trade and may even have the two countries specializing in the same good.

More appropriate are models of recent vintage where firms make deliberate efforts to create knowledge, and imperfect competition allows them to recoup the R&D expenditures required for innovation. One mechanism through which trade raises productivity is by giving producers access to imported intermediate inputs, and by increasing the incentive for firms to create these inputs. A second mechanism is when knowledge spillovers are transmitted through trade. In models that incorporate intermediate inputs, trade either increases the range of available manufactured inputs (Ethier 1982) or provides access to newly invented, state-of-the-art intermediate inputs (Grossman and Helpman 1991a). The case where trade transmits knowledge is developed in Grossman and Helpman (1991b).

Overall, the trade and growth literature predicts that trade can lead to both static and dynamic gains in productivity growth. Productivity growth will occur when industry composition is restructured towards high-productivity industries. Moreover, growth can occur within individual industries. The models described above generally investigate movements from autarky to free trade, but one would expect that tariff reductions would have effects similar to opening a country to trade. Thus, the models that generate greater technological advances for individual industries can provide a theoretical basis for Sawchuk and Trefler's finding that FTA tariff reductions raised productivity within 4-digit manufacturing industries in Canada.

THE EMPIRICAL LITERATURE

A NUMBER OF EMPIRICAL STUDIES have investigated the relationship of trade, or trade liberalization, to output growth and technological advance in industries. By and large, this literature fails to consistently find that openness to trade or the volume of trade is associated with greater productivity growth within countries. Evidence about the impact of trade liberalization on industry-level productivity is also inconclusive.

One strand of this literature uses cross-country growth equations to estimate the link between trade and growth in total factor productivity. It uses growth accounting to relate growth in output to growth in factors, with the residual serving as an estimate of total factor productivity. Measures of openness to trade are then added to see whether the residual can be explained by these variables. Levine and Renelt (1992) consider a number of different measures of trade policies for more than 100 countries over the period 1960-89, but they fail to find a consistent relationship between openness to trade and long-run growth. The industry-level analysis of Harrison and Revenga (1995) reveals a negative relationship between trade and productivity in U.S. 4-digit industry data over the period 1959-84. On the positive side, the U.S. International Trade Commission (1997) finds that tariffs lower productivity and that a high export-to-output ratio raises productivity in sector-level regressions for a sample of 13 OECD countries (including Canada) over the period 1980-91. The Economic Planning Advisory Commission of Australia (1996) also uses sectoral data for 14 OECD countries and finds that a one percentage point cut in tariff rates raises total factor productivity by 3.4 percent over a period of 19 years. It finds that most of the effects occur a number of years after the tariff reduction. Frankel and Romer (1999) evaluate 150 countries in 1985 and employ instrumental variable techniques to show that trade has a large effect on income, but the relationship is only moderately statistically significant.

Further support for the proposition that openness promotes productivity is found in studies examining research and development (R&D) spillovers between nations. Coe, Helpman and Hoffmaister (1995) find that developing countries with a high import-to-GNP ratio enjoy stronger R&D spillovers from developed countries.

Other studies examining productivity in specifications other than growth equations include that of Tybout and Westbrook (1995), who analyze productivity in Mexican plants between 1984 and 1990, a period during which Mexico underwent significant trade liberalization. The authors find that average costs fell and productivity rose during the period, and that there is weak evidence of a positive correlation between movements in these performance measures and the extent of trade liberalization.

Another set of studies relates trade liberalization to industry output, the scale of operations in industries, or employment. Head and Ries (1999b) examine the effects of tariff changes under FTA on the number and average size of firms in 230 Canadian manufacturing industries over the period 1988-94. The authors find that the results depend on whether the tariff reductions occur in Canada or in the United States. U.S. tariff reductions led to a 9.8 percent increase in average plant size, which was largely offset by the 8.5 percent reduction caused by Canadian tariff cuts. These effects were larger in industries experiencing high levels of entry and exit. Head and Ries (1999a) consider the effects of tariff reductions on the Canadian industry share of North American (U.S. and Canadian) output in 4-digit manufacturing industries. Like Sawchuk and Trefler do in their study, they consider a single measure of (bilateral) tariff changes as opposed to investigating the effects of U.S. and Canadian tariff reductions separately.[5] The authors find heterogeneous effects across industries. Canadian industries with relatively low Canadian demand or high natural-resource intensity fared best. We interpret these results as reflecting improved access to a large market (low-demand industries) or comparative advantage (natural-resource intensity). Finally, Gaston and Trefler (1997) use 2-digit SIC data to relate employment changes to tariff changes, and add the employment level of corresponding U.S. industries to control for industry-specific effects shared by North American manufacturers. They find marginally significant negative effects of tariff reductions on employment.

Other empirical studies reveal that the FTA has trade-stimulating effects. Schwanen (1993) divides industries according to whether they are liberalized under the FTA or not. He compares Canada's trade gains in each group to the United States and to the rest of the world and finds that trade increased fastest among liberalized goods destined for the United States. He concludes from this observation that the FTA had trade-stimulating effects. Clausing (2000) uses very disaggregated U.S. import data (the 10-digit categories of the Harmonized Classification System) and relates the volume of imports to tariff rates in order to estimate the trade-creation effects of the FTA. She finds extremely large effects and concludes that the FTA is responsible for over one-half of the $42 billion increase in U.S. imports from Canada over the 1989-94 period.

Sawchuk and Trefler's study is a welcome addition to this empirical literature. Their data differencing technique eliminates industry-specific and business-cycle effects that may confound the analysis. They demonstrate that their results are robust to different specifications and sample periods. Their finding that the FTA reduced employment and output in Canadian industries is consistent with the size disadvantage predicted by the home-market effect. The positive result for productivity adds to the growing body of evidence that tariff reductions enhance productivity within industries in developed countries. Sawchuk and Trefler's use of tariffs, rather than a measure of openness — such as trade to output — commonly found in the literature, makes it easier to see that causality runs from openness to productivity, not the reverse.

Sawchuk and Trefler's choice to examine changes within 4-digit industries somewhat limits the scope of their findings. For example, their investigation would not reveal tariff changes that promote some manufacturing industries but harm others. Also, they do not measure advances in manufacturing productivity stemming from a restructuring towards high-productivity industries and away from unproductive ones.[6] Nonetheless, even if their analysis does not reveal every effect of the Agreement, it identifies some very pronounced effects which imply that even somewhat moderate tariff cuts can have a profound impact on some industries. These results are clearly important for policy formulation.

FDI AND PRODUCTIVITY

THE STUDY ENTITLED *Are Canadian-Controlled Manufacturing Firms Less Productive Than Their Foreign-Controlled Counterparts?*, by Someshwar Rao and Jianmin Tang, examines the relative productivity of foreign- and Canadian-controlled firms in Canada. Using firm-level data generating 1,810 observations over the 1985-95 period, the authors report three sets of results. The initial results test whether foreign-controlled firms have significantly different factor productivity than domestically controlled firms in Canada, based on estimates of a Cobb-Douglas production function that includes controls for firm characteristics. The second set of results uses the estimated coefficients to measure what part of the productivity gap between foreign- and domestically controlled firms is attributable to labour quality, vintage, unionization, exporting, and firm size. The third set of results uses the estimates to ascertain the extent to which the productivity gap is caused by differences in industry composition.

The results reveal that foreign-controlled firms are more productive than domestically controlled ones, although the gap of 25 percent observed over 1985-88 narrowed to 16 percent during the period 1989 to 1995. In addition, the authors find that productivity increases with labour quality, as measured by the share of white-collar workers in total employment. The estimates also show that larger scale is associated with higher productivity, but that unionization has a negative effect.

None of the aforementioned results is surprising. The observation that highly foreign-controlled firms are most productive has been made for both Canada and the United States. The firm characteristics enter with signs that theory and common sense would predict. What is striking about these findings is the magnitude of the foreign productivity advantage and the fact that controlling for firm characteristics has a negligible impact on the productivity gap. These results contrast with earlier ones presented in Globerman, Ries and Vertinsky (1994), who find that differences in size account for differences in labour productivity. In this study, the sample firms are mostly publicly traded, with an average employment exceeding 3,000. Thus, the Canadian sample does not include very small firms that one would expect to have low productivity. Nonetheless, these large Canadian firms have dramatically lower productivity.

In thinking about differences between the two types of firms that might give rise to the measured productivity gap, we considered whether foreign-owned firms could get a large amount of unmeasured, white-collar labour services from the foreign parent firm. As an unmeasured input, we anticipated that this might be a source of the difference in productivity. However, the study's results do not support this conjecture. Foreign-controlled firms do have a lower white-collar share of employment, consistent with the notion that some of these inputs come from headquarters and are not measured on the affiliate income statements. However, the positive and significant coefficient on the white-collar share of employment refutes the hypothesis that a low (measured) white-collar share in foreign affiliates is associated with greater productivity. Instead, the higher average white-collar share of domestically owned firms narrows the productivity gap.

The authors also put to rest the hypothesis that industry composition differences explain average productivity differences. While the study shows major differences in the industry composition of foreign-controlled and domestically controlled firms, it turns out that Canadian firms tend to concentrate in high-productivity industries. Thus, if the industry composition of the two groups were identical, the productivity gap would be even higher.

In the ensuing sections, we briefly provide some theoretical background for the analysis. We then proceed to place the contribution of this study in the context of the empirical literature and suggest further areas of inquiry.

THEORETICAL BACKGROUND

MOST THEORIES CONCERNING FDI start with the premise that foreign firms possess some type of asset that enables them to compete with local firms despite their unfamiliarity with consumers, distribution networks, language, business practices, etc. For example, the foreign firm may have proprietary knowledge of a superior technology. In the international business literature, these assets are known as *ownership advantages*. Within the economic literature, Markusen (1995) considers 'headquarter services' that can be supplied at low cost to foreign affiliates. Ownership advantages linked to low-cost headquarter services may enable a foreign affiliate to produce at a lower cost than its domestically controlled counterparts. Rao and Tang's study can be viewed as evidence in support of the proposition that multinationals hold production advantages vis-à-vis their domestic counterparts.

An important area of policy analysis concerns the contribution of foreign investment to growth. There are a variety of avenues through which FDI can contribute to growth. First, to the extent that it does not crowd out local investment one for one, it can add to the stock of capital and generate increased output. Second, investment by multinationals may provide more productive capital than that of domestically controlled manufacturers, and may contribute to growth that way. Finally, knowledge spillovers emanating from foreign affiliates can increase the productivity of domestically controlled firms. The analysis performed by Rao and Tang does not address the extent to which foreign investment crowds out domestic investment, or whether the high productivity of foreign affiliates spills over to domestically controlled manufacturing operations. However, their finding that foreign-controlled firms are more productive indicates that foreign investment is a source of economic growth in Canada.

CONTRIBUTIONS TO THE EMPIRICAL LITERATURE

THE HIGHER AVERAGE PRODUCTIVITY of foreign-controlled firms relative to domestically controlled firms has two explanations. First, it may be that within each industry, foreign affiliates outperform home firms. Alternatively, foreign-owned firms may disproportionately concentrate in high-productivity industries. Indeed, seeking high returns, they may choose to enter only industries where productivity is high.

The study employs a data set that enables the researchers to distinguish these alternative explanations of high foreign affiliate productivity. Studies using cross-sectional industry information relate variation in productivity to some measure of foreign affiliate activity in industries. A positive relationship is consistent with the hypothesis that foreign-controlled firms are more productive, but it may also reflect the fact that foreign affiliates choose to enter industries where productivity is high. The firm-level data used in this study makes it possible to distinguish between the alternative explanations of higher average productivity of foreign-controlled affiliates. They allow the researchers to employ industry dummy variables that capture productivity differences across firms that are common to all firms in a given industry.

The results presented in Table 3 of their study establish that foreign-controlled firms are more productive than domestically controlled firms. Since the specifications include controls for firm characteristics, these differences are not a consequence of difference in industry, size, and other firm characteristics. Thus, within industry, foreign-controlled firms are more productive. One should note, however, that Rao and Tang apply industry controls at a fairly high level of aggregation (roughly 2-digit SIC). Examples of 2-digit industries are Electrical Machinery, and Transportation Equipment, each of which, of course, contains sub-industries with varying levels of productivity. Thus, their findings may partly reflect differences in industry composition across sub-industries within 2-digit industries.

Few studies have access to data that allow measurement of productivity differences across firms within industries. Globerman et al. (1994) use a sample of plants in 21 4-digit industries in Canada for the year 1986. Unlike Rao and Tang, these authors do not use a measure of capital, and thus cannot estimate multifactor productivity. The two studies lead to the common finding that foreign-controlled firms are more productive than domestically owned firms.

However, unlike Rao and Tang, they find that differences disappear when controlling for size.

Doms and Jensen (1998) examine a sample of 115,139 U.S. establishments, of which 4,463 are foreign-controlled. Like Rao and Tang, they estimate factor productivity by fitting a Cobb-Douglas specification and calculating residuals. The much larger number of observations enables them to fit regressions separately to 4-digit-level industries. This is important given the expectation that factor intensities may vary across industries. Like the Canadian studies, they find that foreign-controlled firms are more productive than domestically controlled ones. They also find that these differences persist even after controlling for industry, size, plant age, and state. Doms and Jensen's results are highly complementary to those of Rao and Tang. Foreign-controlled firms have higher factor productivity than domestically controlled firms and the differences are not attributable to industry composition or differences in firm characteristics.

Doms and Jensen also examine the performance of U.S. plants owned by U.S. multinationals. They divide their sample into plants owned by U.S. multinationals, foreigners, large U.S. firms, and small U.S. firms. They find that among these four groupings, total factor productivity is highest for plants owned by U.S. multinationals. Foreign-owned plants, while more productive than the average U.S. plant, are actually less productive than plants owned by U.S. multinationals. This raises the question as to whether Rao and Tang would find a similar result if they had the data to identify Canadian domestic firms that are multinationals. One would expect that Canadian multinationals might have higher productivity than Canadian firms operating only in the domestic market. However, whether Canadian multinationals perform as well as foreign multinationals is unclear. Presumably, the foreign sample used by Rao and Tang is dominated by U.S. ownership. If U.S. multinationals enjoy extremely high levels of productivity as suggested by Doms and Jensen's study, Canadian multinationals will likely not perform as well as affiliates of U.S. multinationals.

As stated previously, the infusion of productive foreign capital serves as a source of economic growth in host countries. Thus, the results of Rao and Tang's study establishing that foreign-controlled firms have a relatively high productivity are complementary to those of studies identifying a link between FDI and overall productivity growth in the host country. Borensztein, De Gregorio and Lee (1998) use a panel of 69 countries over the period 1970-89 to investigate the role played by FDI in economic growth. They find that FDI promotes growth by increasing the capital stock as well as overall factor productivity. However, the latter result depends on the presence of a threshold level of human capital in the host country so that it has the ability to absorb new technology. Similar results are found by de Mello (1999), who examines

32 countries over the period 1970-90. He shows that FDI is most efficiency-enhancing in host countries that are relatively technologically advanced. Focussing on individual host countries, Barrell and Pain (1997) find that FDI raised technological progress in West Germany and manufacturing in the United Kingdom. Finally, Gera, Gu and Lee (1999) determine that FDI is associated with lower costs and higher productivity in Canada over the period 1973-92.

Having established that foreign-controlled firms are more productive than domestically controlled ones, the next important issue is how this could benefit Canada. On the surface, one may question whether Canada gains by the presence of productive foreign-controlled firms. There would be little gain if foreign owners captured the surplus associated with high productivity in the form of excess profits. However, there are a number of mechanisms through which productive foreign firms may increase Canada's welfare. First, productive foreign-controlled firms can sell output at lower prices than their Canadian counterparts resulting in gains to consumers and firms that purchase intermediate inputs. Second, some of the surplus created may be paid to workers in the form of higher wages. Finally, foreign-controlled firms may transmit knowledge to Canadian firms, making Canadian-controlled firms more productive.

The empirical evidence on the benefits of productive foreign firms for host country welfare is limited. A number of studies show that foreign-controlled firms pay higher wages. The Globerman et al. (1994) study of establishments in 21 industries in Canada for the year 1986 reveals that foreign affiliates pay over 20 percent higher wages then do domestically owned firms. These differences, however, vanish when controlling for capital intensity and firm size. Doms and Jensen's (1998) study of U.S. establishment-level data for 1987 also shows that foreign affiliates pay 20 percent higher wages than their domestically owned counterparts. Moreover, these differences persist even after controlling for plant size and age, industry, and state, with foreign affiliates paying on average a 7-percent wage premium. However, as with their productivity results, the differences are entirely due to the performance of U.S. plants not owned by U.S. multinationals. U.S. multinationals pay higher wages than their non-multinational counterparts as well as foreign-owned firms. Using a panel of U.S. industries for 1987 and 1992, Feliciano and Lipsey (1999) arrive at somewhat different results than those of Doms and Jensen. They find that while average wages in foreign affiliates are higher than those paid in domestically owned firms, the differences disappear with the inclusion of controls for size and location. However, wage premiums appear to be paid in foreign-owned non-manufacturing industries. The important result coming out of all these studies is that foreign firms appear to pay higher wages. Even if higher wages are associated with larger size and capital intensity, they still represent a gain to the host economy. Thus, the empirical literature indicates that higher wages are a means through which the host economy gains from productive foreign-controlled firms.

Evidence on the effect of foreign-controlled firms on domestically controlled firm productivity is mixed. Results indicating that the productivity levels of domestically owned firms increase along with the foreign-affiliate share of the industry appear in Globerman (1979) for Canada, and in Blomstrom (1986) for Mexico. Aitken and Harrison (1999) find a positive relationship between increased foreign equity participation and productivity in Venezuela plants. However, an increase in foreign investment is associated with a decline in the productivity of domestically controlled plants.

Other studies provide indirect evidence on productivity spillovers. Aitken, Harrison and Lipsey (1996), as well as Feliciano and Lipsey (1999) find that the wages paid in an industry by domestically owned firms in the United States rise with the share of foreign-controlled firms in that industry. One interpretation of this result is that foreign affiliates increase the productivity of domestically owned firms.

Rao and Tang's study provides striking results. Among large, publicly traded firms in Canada, foreign-controlled firms were 16 percent more productive than their domestically owned counterparts over the period 1989-95. While firm characteristics such as size, unionization, and labour quality matter for productivity, they do not influence the productivity gap. Moreover, if industry composition were the same for foreign-controlled and domestically owned firms, that gap would be even larger. These results are consistent with the theory suggesting that foreign affiliates need to be more productive in order to compete in foreign environments. The magnitude of the difference indicates that foreign-controlled firms may provide substantial welfare benefits to Canada.

Conclusions and Future Research

Both Sawchuk and Trefler's study and Rao and Tang's study provide useful insight for policy formulation. Canada has steadily removed barriers to trade and investment through its participation in the World Trade Organization and the North American Free Trade Agreement. It is thus important to assess the consequences of closer international economic integration.

The subject of the conference where these studies were presented is productivity, with Canada's lagging performance as a backdrop. The studies undertaken by Sawchuk and Trefler, and by Rao and Tang reveal that neither tariff reductions under the FTA nor an open policy towards foreign investors are to blame for the relatively low productivity growth in Canada. Indeed, Canada's productivity would have been lower still with higher tariff barriers between the United States and Canada or with less foreign investment.

The analysis provided in these studies suggests a couple of areas where further research may be valuable. With regard to Sawchuk and Trefler's study, the authors claim that the long-run winners from the FTA were the stakeholders of efficient establishments. Support for this contention would require investigating the effects of the FTA at the firm level. There are a number of interesting questions to explore based on Melitz's model of heterogeneous firms:

- Scale: Did tariff cuts have differential effects on Canadian firms? Melitz's analysis suggests that scale would increase for efficient (large) firms and decrease for inefficient (small) firms.

- Exit: Did tariff cuts increase the probability of exit by inefficient firms? Increased import competition would induce exit.

The analysis of trade liberalization effects across firms within a particular industry requires a different data set than the one employed by Sawchuk and Trefler. Such a study would be complementary to theirs by pinpointing the source of industry-level productivity gains they identify.

Likewise, there could be a number of useful extensions to Rao and Tang's analysis. The authors provide strong evidence that foreign-controlled firms are productive. However, their analysis is based on a fairly small sample (1,810 firms) that makes it difficult to introduce highly disaggregated industry fixed-effects. Instead, they control for industry effects at the 2-digit SIC level. Consider the Transportation industry, for example, to see how aggregation may influence their results. Table 6 of their study shows that the ratio of Canadian-controlled firms productivity to foreign-controlled firms productivity in the Transportation industry was 0.65 over the period 1993-95. Transportation includes a number of disparate sub-industries such as motor vehicles, aircraft, and trains. Let's suppose that within the Transportation industry, Canadian-controlled firms are disproportionately represented in low-productivity industries and, therefore, have lower average productivity within the Transportation industry. The proper control for this difference in composition would require industry-fixed effects at a higher level of disaggregation. While there is no reason to believe that the 2-digit level of aggregation favours foreign-controlled firms, further research might test whether employing fixed effects at, say, the 4-digit level influences the results.

Additional extensions of Rao and Tang's study would be an investigation of avenues through which productive foreign-controlled firms benefit Canada. Do foreign-controlled firms pay higher wages after controlling for any differences in worker quality? Is the productivity of domestically controlled firms higher in industries where there are a large number of foreign firms? An examination of these alternative mechanisms through which foreign-controlled firms provide spillover benefits would supplement their analysis.

This chapter endeavoured to provide a survey of the theoretical literature specifying the linkages between openness to trade and foreign investment, and industry performance. Within this theoretical framework, the empirical essays described in this review investigate whether trade and FDI influence productivity and measure the magnitude of the effects. Sawchuk and Trefler's study and Rao and Tang's study combine unique data and strong empirical techniques to provide valuable contributions to this area of inquiry.

ENDNOTES

1 His technique does not eliminate every feature of the macro-economic environment that may influence industry performance. For example, the real exchange rate behaved differently in the two periods. If industry-specific real exchange rate effects were correlated with industry-level tariff reductions, then the coefficient on the latter variable would be biased.
2 Some of the trade and growth literature maintains traditional trade theory's assumption of constant returns to scale. We will focus on theories that incorporate increasing returns and imperfect competition.
3 Head, Mayer and Ries (2000) show that this prediction also holds in a model where output is homogeneous and firms sell to segmented home and foreign markets.
4 The hypothesis is proposed in Eastman and Stykolt (1967) and is formalized in Muller and Rawana (1990).
5 The defence for this modelling decision is the high degree of correlation between Canadian and U.S. tariff reductions under the FTA and consequential difficulties in distinguished separate effects.
6 Trefler argues in his conclusion that the FTA caused "dramatically higher productivity in low-end manufactures and resource reallocation to high-end manufactures." He does not, however, provide strong evidence to support this statement. He associates high initial tariffs with low-end manufactures, and productivity rose the most in those sectors. However, he does not explicitly examine resource reallocation from high- to low-productivity sectors.

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16

A Time to Sow, a Time to Reap: The FTA and its Impact on Productivity and Employment

COMPETING CONTENTIONS – IS THERE NOW A VERDICT?

THE CANADA-U.S. FREE TRADE AGREEMENT (FTA) remains one of the most contentious pieces of economic legislation ever enacted in Canada. Remarkably, the FTA is far from being viewed as a success by either end of the political spectrum. The Canadian Labour Congress fingers the Agreement as the cause of job losses that tragically racked manufacturing in the early 1990s (Jackson, 1996). And even the business community complains about the ultimate FTA failure: *lagging* productivity growth (Rubin, 1997) — in apparent contradiction to the forecasted improvements in productivity that have always been at the heart of the proclaimed benefits.

While the nay-sayers dominate public discussion, the arguments, pro and con, have often been devoid of hard facts, despite efforts made by the research community to provide evidence and thoughtful analysis on the matter (e.g., Gaston and Trefler, 1994, 1997; Trefler, 1997; Head and Ries, 1997, 1999a,b; Feinberg and Keane, 1998; Feinberg, Keane and Bognanno, 1998; and Beaulieu, 2000). Clearly, the court of public opinion is not easily convinced. The jury remains out on whether the FTA productivity benefits live up to their promise and whether these benefits compensate sufficiently for any employment and business losses. Consequently, two questions still beckon: Is it possible to summon clear, convincing evidence of the FTA's impact? Is it possible to separate out the *real* from the *perceived,* and facts from appearance?

Trefler (2001) takes us a long way towards providing an answer. In particular, he calculates that the FTA reduced manufacturing employment by 5 percent between 1988 and 1996, and by 15 percent in the manufacturing industries that experienced the deepest tariff cuts. On the other hand, he estimates that the FTA raised manufacturing labour productivity by 5 percent, and by a remarkable 17 percent in the manufacturing industries hardest hit by the FTA tariff cuts.

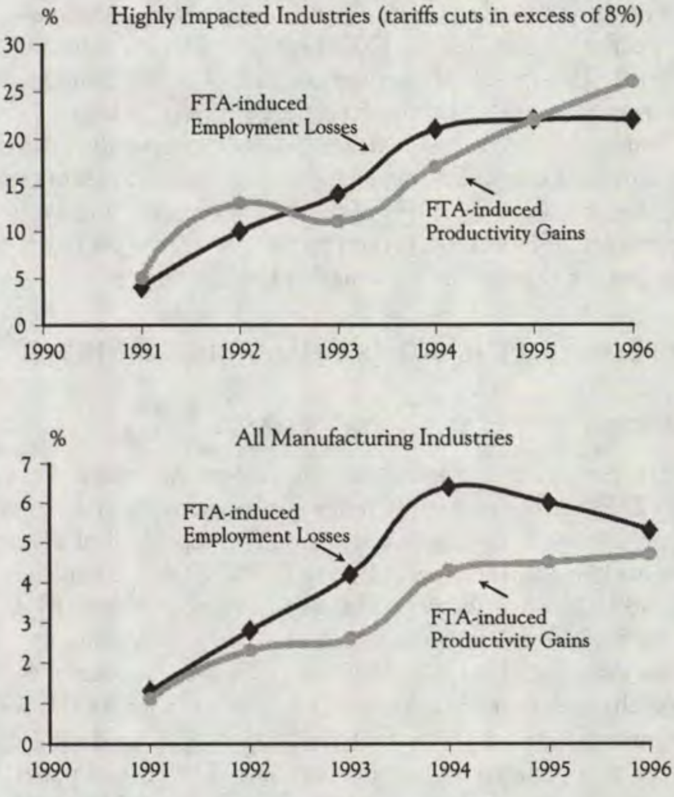
There remains, however, two unanswered questions stemming from Trefler's (2001) research. First, he asserts rather than establishes that the employment losses were a short-run and, by implication, temporary phenomenon. Second, he leaves open the question of whether there were net benefits accruing from the FTA. In particular, timing matters. For example, suppose that the employment losses were permanent and came immediately after implementation of the FTA, whereas the bulk of productivity gains came only in 1996. Then, for a policy maker with a high discount rate, employment losses could outweigh any productivity gains and the FTA could be deemed a failure.

In this chapter, we will confront the two issues left unanswered by Trefler's (2001) analysis. First, we will provide evidence that the employment losses did not significantly predate the productivity gains. The argument is illustrated in Figure 1, which plots our estimates of the FTA impact on employment and labour productivity. (We emphasize that these plots are the output of a complex estimation procedure.) Recall that the FTA was implemented on January 1, 1989. Figure 1 tracks FTA effects starting in 1991. The top panel plots the FTA impacts on those industries that, by 1996, had experienced FTA-mandated tariff cuts in excess of 8 percent. As can be seen, the employment losses arrived early and plateaued by 1994. However, the productivity gains also arrived early and, unlike the employment losses, continued accruing throughout the period. Even for all of manufacturing, illustrated in the bottom part of Figure 1, the employment losses did not arrive much earlier than the productivity gains.[1] There is thus no sense in which the employment costs were front-ended relative to the productivity gains. It follows that even our fictitious high-discount-rate policy maker should not worry about the timing of the FTA costs and benefits. Since the FTA-induced employment costs and productivity benefits accrued at roughly the same rate, any assessment of the FTA must be independent of the discount rate used.

Second, we will provide evidence that while the industries that experienced the deepest tariff cuts saw their employment level fall, the remaining industries experienced an increase in their employment level. Part of the evidence for this stems from the fact that, over the 1988-2000 period, Canadian manufacturing employment rose by 0.7 percent. In contrast, manufacturing employment declined in almost all of the most industrialized nations (for example, it fell by 4.4 percent in the United States). This implies that the FTA did not induce any permanent job losses in manufacturing. The observation of no net employment losses is entirely consistent with standard Ricardian trade theory, which predicts that free trade will shift employment out of low-end,

FIGURE 1

TIMING OF EMPLOYMENT LOSSES AND PRODUCTIVITY GAINS



Source: Authors' calculations from Tables 7 and 9.

protected industries and into high-end, unprotected industries. Re-framing our facts in the context of this theory, the permanent effect of the FTA on employment was not a reduction in employment, but a reallocation of workers toward more productive activities.

Figure 1 also provides an interesting way of looking at Trefler's (2001) results on employment and productivity. Trefler was only interested in the 1996 results. In the top panel of Figure 1, which deals with the highly impacted industries, we can see that the FTA reduced employment by an unimaginable

22 percent and raised productivity by a remarkable 26 percent. These numbers represent both the huge costs and huge benefits of the FTA.[2]

The chapter is organized as follows. The next section, entitled *What Do Simple Time-series Comparisons Show?*, provides a broad overview of Canada's key manufacturing performance indicators since the implementation of the FTA. The third, entitled *Isolating the FTA Effect – Method of Analysis and Data*, develops a modification of Trefler's (2001) methodology for assessing the impacts of the FTA. This modification allows us to look at the timing issues that are at the heart of this study. The fourth section, entitled *Findings – Productivity Growth and Employment Losses*, presents the results that underlie Figure 1. The fifth section, entitled *General Equilibrium Considerations*, critiques our approach by observing that it ignores the effect of the FTA in reallocating workers from high-tariff to zero-tariff industries. It then provides evidence on the magnitude of this effect. Our conclusions are presented in the last section.

WHAT DO SIMPLE TIME-SERIES COMPARISONS SHOW?

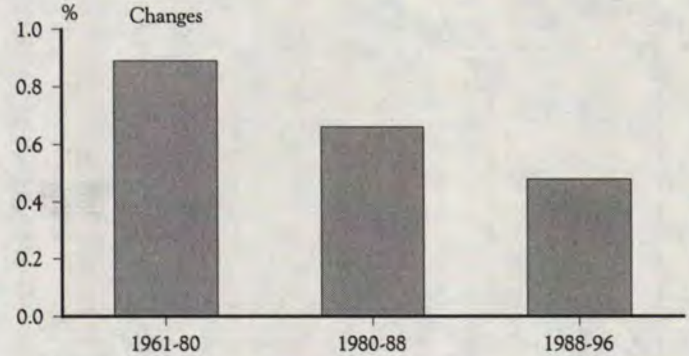
CANADA'S RECENT PRODUCTIVITY PERFORMANCE

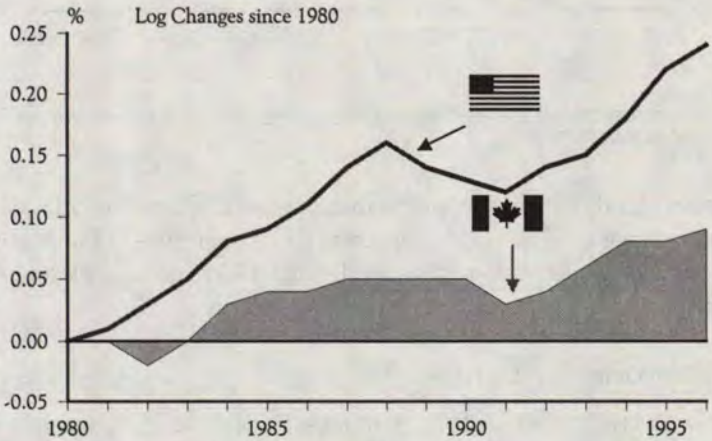
PRODUCTIVITY IS COMMONLY MEASURED in one of two ways. Total factor productivity (TFP) measures the difference between output and the inputs of capital, labour, energy, materials and services. The top panel of Figure 2 displays movements in manufacturing TFP growth. The FTA was implemented on January 1, 1989. Figure 2 depicts changes over the 8-year FTA period (1988-96),[3] the 8-year pre-FTA period (1980-88), and the remaining period for which data are available (1961-80). 1980 and 1988 were chosen as base years for measuring changes over these periods because each marks the peak of a business expansion. Figure 2 shows that productivity growth during the FTA period has been weak relative to past performance. The bottom panel displays the now famous observation about diverging Canadian and U.S. TFP growth. In that panel, we have chosen 1980 as the base year since up until then Canadian labour productivity had tracked its U.S. counterpart very closely. (Indeed, the picture is identical if 1961 is chosen as the base year.) Whatever the productivity gap was in 1980, by 1988 it had widened by 11 percentage points, and by 1996 it had widened another 4 percentage points. Annualizing these numbers for the FTA period, the Canadian productivity growth rate of 0.5 percent was overshadowed by the U.S. productivity growth rate of 1 percent.

Since the Agreement was expected to force Canadian firms into a more competitive position vis-à-vis U.S. firms, Figure 2 is often used to argue that the Agreement was a failure. In this view, the depreciation of the Canadian dollar is the only reason why Canada has stayed competitive (Rubin, 1997).

FIGURE 2

MULTIFACTOR PRODUCTIVITY GROWTH IN MANUFACTURING





Canadian and U.S. TFP Growth

Source: Canadian data are the Fisher value-added multifactor productivity (MFP) measure from CANSIM, as updated on March 23, 1999. The U.S. data are the MFP series taken from http://www.bls.gov/news.release/prod3.t01.htm, as updated on February 11, 1999.

FIGURE 3

UNIT LABOUR COSTS IN CANADA AND THE UNITED STATES

Source: Data are from the U.S. Bureau of Labor Statistics, foreign labor statistics home page, as updated on June 23, 1999.

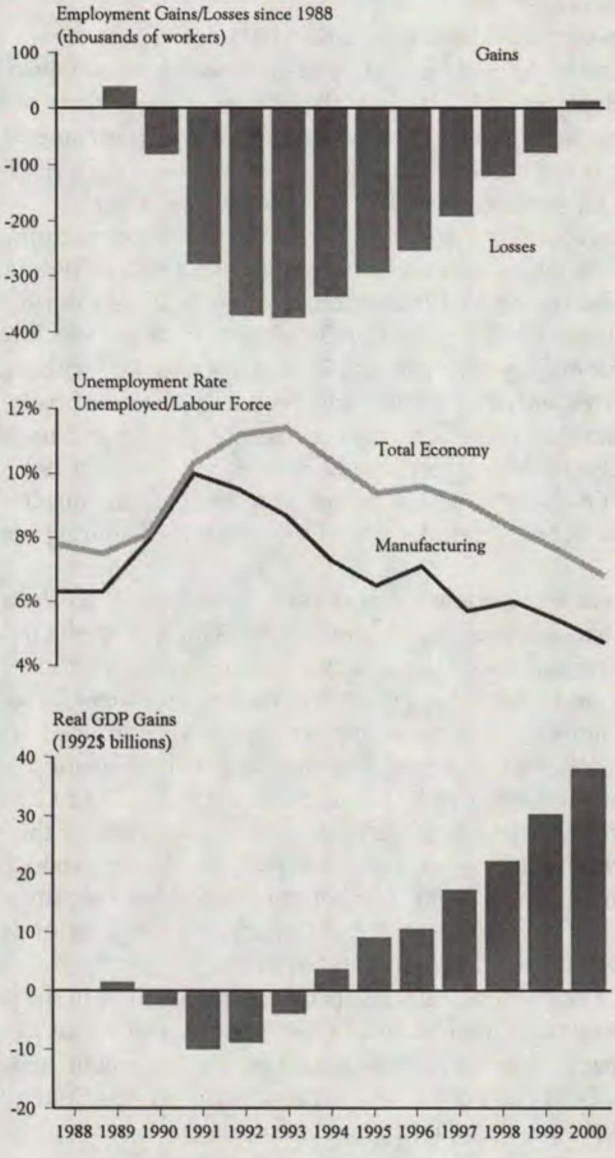
Figure 3 lends partial support to this argument. Between 1988 and 1996, Canadian relative to U.S. unit labour costs (both expressed in U.S. dollars) fell by 7 percent. However, the data series discussed next paint a picture of more solid Canadian competitiveness.

OTHER ECONOMIC INDICATORS

EARLY ON IN THE DEBATE ABOUT THE MERITS OF THE FTA, interest was focused on the collapse of manufacturing employment. The top panel of Figure 4 shows the enormous employment losses experienced in manufacturing. The left-hand scale shows the cumulative reduction in manufacturing employment since 1988. In 1993, there were almost 400,000 fewer employees in manufacturing than in 1988. This amounted to a staggering loss of 17 percent of the 1988 work force. Many have blamed the FTA for these lost jobs. From the current perspective, these losses appear to have been short-lived (which is not to minimize them). Manufacturing employment in 2000 was 0.7 percent higher than in 1988. And the middle panel of Figure 4 reveals that there has been no long-run impact on the unemployment rate in Canada overall.

FIGURE 4

MANUFACTURING EMPLOYMENT, UNEMPLOYMENT RATE AND REAL GDP



Source: CANSIM.

We also plot the unemployment rate for manufacturing. This is defined as those unemployed whose last job was in manufacturing divided by manufacturing employment. Both overall and for manufacturing, unemployment rates were actually lower in 2000 than in the boom year 1988 that immediately preceded implementation of the FTA.

Some commentators have argued that the unemployment rate is not relevant because the FTA forced a rise in part-time employment. Given the rise of part-time employment in Canada, so the argument goes, many of those who worked full-time in 1988 may now be working part-time because of the FTA. This possibility is not backed up by the data on average weekly hours in manufacturing. Weekly hours stood at 38.9 in *both* 1988 and 2000.[4]

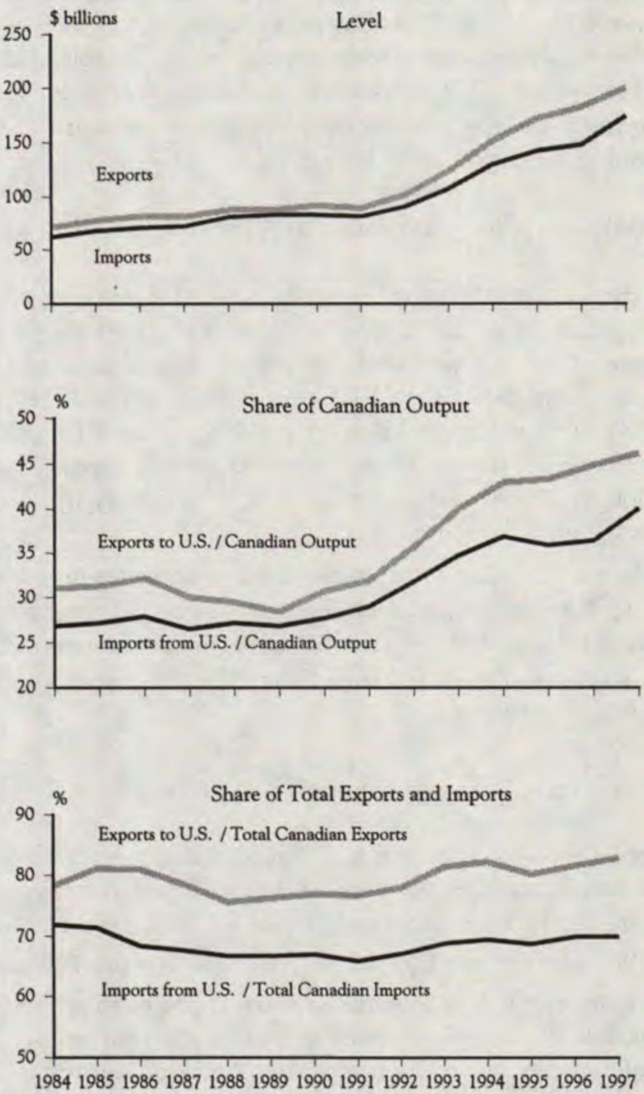
The bottom panel of Figure 4 plots real GDP for manufacturing. One can again see the large hit to manufacturing of the early 1990s followed by a strong recovery. At the trough in 1991, manufacturing GDP was down 10 percent from its 1988 level. By 2000 it was up 36 percent from its 1988 level. The information about employment and real GDP do not sit well with indicators of poor Canadian productivity growth. Figure 4 tells a story of rising GDP per worker. The fact that manufacturing employment, output and unemployment rates have all sharply improved since the recession of the early 1990s is suggestive of an FTA-induced restructuring of Canadian manufacturing. This strengthens the economic outlook for Canada's manufacturing sector under free trade.

Another piece of evidence that is hard to reconcile with the contention that the FTA had a negative impact on employment and productivity appears in Figure 5. There was unprecedented export and import expansion throughout the 1990s (see the top panel of Figure 5). This growth cannot be explained by exchange rate movements because imports should have declined as a result of the Canadian dollar devaluation. The middle panel of Figure 5 shows that trade growth outstripped growth in manufacturing output. The Canadian ratio of trade to output of close to 40 percent makes Canada one of the most open economies in world history. One would not expect lagging productivity to be associated with an export boom. The bottom panel shows that since 1988, the United States has increased its share of Canadian trade. This trade-diversion effect is precisely what the FTA is expected to do.

To recap, a simple time series comparison of productivity in the years before and since the implementation of the FTA may lead to an unjust indictment of the FTA's impact. Many other series, such as the enormous manufacturing boom in GDP, GDP per worker, and exports to the United States all actually paint a picture of strong productivity performance.

FIGURE 5

CANADIAN IMPORTS FROM AND EXPORTS TO THE UNITED STATES



Source: Authors' calculations.

ISOLATING THE FTA EFFECT – METHOD OF ANALYSIS AND DATA

A DEFECT OF THE PREVIOUS SECTION'S ANALYSIS was its reliance on aggregate time series. By implicitly attributing all post-1988 trends to the FTA, the analysis ignored the role of other sources of change. In this section, we will use more sophisticated econometric techniques to isolate the role of the FTA. Let $i = 1, \ldots, 213$ index the 213 industries in our sample, let t' index years, and let $Y_{it'}$ be employment or labour productivity of industry i in year t'. The FTA was implemented on January 1, 1989. Let's define

$$(1)\quad \Delta y_{i1}(t) \equiv (\ln Y_{i,1988+t} - \ln Y_{i,1988})/t \quad \text{and} \quad \Delta y_{i0}(t) \equiv (\ln Y_{i,980+t} - \ln Y_{i,1980})/t.$$

$\Delta y_{i1}(t)$ is the average log point change in $Y_{it'}$ over the first t years of the FTA period. $\Delta y_{i0}(t)$ is the average log point change in $Y_{it'}$ over the first t years since 1980. Note that t' is a year while t is the number of years since either 1980 or 1988. We have data for the FTA period (1989-96) and the pre-FTA period (1980-88). Let s index periods, with $s = 1$ being the FTA period and $s = 0$ being the pre-FTA period. Then, we may compactly capture the above with the notation $\Delta y_{is}(t)$, $s = 0,1$ and $t = 1, \ldots, 8$. Note that $\Delta y_{is}(t)$ is expressed as an annual compound growth rate.

Let $\tau_{it'}^{US}$ be the Canadian tariff against the United States in industry i in year t' and let $\tau_{it'}^{ROW}$ be the Canadian tariff against the rest of the world. Then $\tau_{it'}^{US} - \tau_{it'}^{ROW}$ is the FTA-mandated preferential tariff concession extended to the United States. Its average annual change during the first t years of the FTA period ($s = 1$) is

$$(2)\quad \Delta\tau_{i1}^{FTA}(t) \equiv \left((\tau_{i,1988+t}^{US} - \tau_{i,1988+t}^{ROW}) - (\tau_{i,1988}^{US} - \tau_{i,1988}^{ROW})\right)/t\,.$$

For the pre-FTA period, tariff rates were extended on a most-favoured nation (MFN) basis, at least in industries that were not covered by the Auto Pact. Mathematically, for non-Auto Pact industries i and for years $t' \leq 1988$, $\tau_{it'}^{US} - \tau_{it'}^{ROW} = 0$ and $\Delta\tau_{i0}^{FTA}(t) \equiv 0$. We will not need to define $\Delta\tau_{i0}^{FTA}(t)$ for Auto Pact industries because these industries will be eliminated when it comes to estimating our econometric model. We do this in order to ensure that our results are not driven by the automotive sector. As it turns out, however, our results are the same whether or not that sector is included in the econometric work. We will return to this point below.

EXAMINING THE FTA-MANDATED TARIFF CONCESSIONS ($\Delta\tau_{i1}^{FTA}$)

IT IS NATURAL TO ASK whether the FTA tariff cuts were deep enough to have mattered. After all, the average tariff rate against the United States in 1988 in manufacturing was 4.5 percent, a level too low to have had much effect. However, Trefler (2001) makes the following points:

- Tariffs tend to be lowest on less-processed manufactures and highest on processed ones. For Canada, this means that the tariff rate understates the effective rate of protection. Indeed, Canada's average manufacturing tariff rate has historically been half that of its effective rate of protection.
- The pre-FTA distribution of tariff rates across industries was highly skewed, with many industries facing steep tariff rates. For example, of the 213 4-digit Standard Industrial Classification (SIC) industries in Canadian manufacturing, 54 were sheltered behind a tariff in excess of 10 percent. By 1996, no industry had tariffs in excess of 10 percent. For low-end manufacturing, where profit margins are tight, this represents very steep tariff cuts indeed.
- The FTA called for reductions not only in Canadian tariffs against the United States, but also in U.S. tariffs against Canada, and various forms of non-tariff barriers to trade between the two countries. In this regard, it is important to note that the structure of tariffs across industries is similar in Canada and the United States, and that protected industries often receive both tariff and non-tariff protection. Thus, the FTA-mandated Canadian tariff cuts are highly correlated both with the cuts in non-tariff barriers to trade and with the U.S. tariff cuts. In a regression setting, this means that the coefficient on $\Delta\tau_{i1}^{FTA}$ will also be picking up these other effects. That is, our tariff variable will be capturing the broader aspects of the FTA.

The bottom line is that $\Delta\tau_{i1}^{FTA}$ will be capturing FTA effects that are far from being too small to matter.

INFERENCE IN A NON-EXPERIMENTAL SETTING

THE ECONOMETRIC WORK IN THIS PAPER is all about correlating $\Delta\tau_{i1}^{FTA}$ with Δy_{i1}, where Δy_{i1} is the FTA-period change in either employment or labour productivity. In studying this issue it is tempting to draw an analogy with a clinical drug trial. In such a trial, patients are randomly allocated between the treatment and control groups. In our setting, industries facing steep tariff cuts are being treated to the *drug* of free trade. However, the analogy does not go very far because industries that receive the drug (mainly low-end manufacturing) are and were very different from those where tariffs were not cut (high-end manufacturing). Restated, there is no randomization of industries into treatment and control groups. As a result, any difference between the *treated* and *untreated* industries may be spurious: The industries that experienced the deepest tariff cuts may have had non-FTA related characteristics that may have led to falling employment and rising productivity. Ignoring the difference in group characteristics may lead one to incorrectly attribute falling employment and rising productivity to the FTA.

Before reviewing these differences, Table 1 shows the classification of industries into groups that will be used throughout this paper. We divide the industries into four groups, based on the depth of the FTA-mandated tariff cuts between 1988 and 1996. Note that we put a minus sign in front of $\Delta\tau_{i1}^{FTA}$ in order to convert it into a positive number.

We now turn to examining the differences between these four groups. We know that if there were random assignment of industries into the four groups, then the characteristics of these groups would be identical. However, Table 2 shows that this is not the case. In fact, each indicator trends strongly with the depth of the tariff cut. Consequently, we can focus our attention solely on the heavily impacted versus non-impacted industries (and avoid reporting results for the moderately and lightly impacted industries). From Table 2, it is clear that the deeper the FTA-mandated tariff cut, the lower was the industry's labour productivity, capital-labour ratio, and output per plant in 1988. Table 2 also reports results for production and non-production workers. Production workers are involved in shop-floor activities and are less educated on average than non-production workers. Non-production workers include employees in management and other activities that are not directly related to production. In Table 2, we can see that the deeper the tariff cut, the lower were the wages and

TABLE 1

DEFINITION OF INDUSTRY GROUPS

	MINIMUM TARIFF CUT ($-\Delta\tau_{i1}^{FTA}$)	MAXIMUM TARIFF CUT ($-\Delta\tau_{i1}^{FTA}$)	NUMBER OF INDUSTRIES (OBSERVATIONS)
Heavily Impacted Industries	8%	33%	34
Moderately Impacted Industries	4%	8%	51
Lightly Impacted Industries	1%	4%	56
Non-impacted Industries	0%	1%	72

TABLE 2

AVERAGE INDUSTRY CHARACTERISTICS AND SIZE OF TARIFF CUTS, 1988

	HEAVILY IMPACTED INDUSTRIES	ALL INDUSTRIES	NON-IMPACTED INDUSTRIES
Industry Characteristics			
Labour Productivity	0.029	0.043	0.050
Capital/Labour	0.015	0.044	0.061
Output per Plant	0.008	0.027	0.052
Employment and Earnings			
Hourly Wages of Production Workers	$10.92	$14.04	$15.26
Weekly Hours of Production Workers	41.4	41.8	42.2
Annual Earnings of Non-production Workers	$39,017	$42,950	$44,303
(non-production workers)/(all workers)	18%	25%	29%
Trade Characteristics			
Imports from United States/Total Imports	31%	61%	69%
Imports from United States/Canadian Output	9%	28%	51%

Note: All data apply to 1988. Cell entries are unweighted averages across all industries in the group. See Table 1 for the definition of the groups.

weekly hours of production workers, the annual earnings of non-production workers, and the ratio of non-production workers to the total number of workers in 1988. Finally, the deeper the tariff cut, the lower the level of imports from the United States that same year. This is true relative to total imports and relative to Canadian (domestic) production. Clearly, in 1988 the heavily impacted industries looked very different from the non-impacted industries.

TESTING THE EFFICACY OF THE FREE-TRADE "DRUG"

IN A CLINICAL TRIAL SETTING, the average characteristics of patients in the treatment group are identical to the average characteristics of patients in the control group. This is the result of random assignment. In our non-experimental setting, there is a commonly used strategy for dealing with the fact that groups differ in their characteristics. We turn to this now.

We are interested in a regression model that explain the impact of FTA tariff cuts on the growth rates of employment and productivity. For each t, we will examine a model of the form:

$$(3)\quad \Delta y_{is}(t) = \alpha_i + \alpha_s + \beta\Delta\tau_{is}^{FTA}(t) + \gamma\Delta y_{is}^{US}(t) + \delta_i\Delta z_s(t) + \varepsilon_{is},$$
$$s = 0, 1 \text{ and } i = 1, \ldots, N.$$

α_i, α_s, Δy_{is}^{US}, and $\delta_i \Delta z_s$ are regressors that control for the fact that heavily impacted industries are different from non-impacted industries. We will briefly explain each of these regressors. However, before doing so note that Equation (3) will be estimated separately for each t, that is for each choice of number of years in the FTA period (1988, 1988 + t). This will allow us to investigate the timing of the effects of the FTA. This constitutes our new econometric contribution.

Controlling for Secular Growth (α_i)

Figure 6 illustrates a potential pitfall for efforts to assess the FTA. The figure plots the evolution of employment in some fictitious industry, say women's garments, from 1980 to 1996. Looking just at the FTA period, one sees that as the tariff came down, so did employment. The obvious inference is that the FTA reduced employment. Clearly, this inference is misleading: a look at the pre-FTA period shows a secular downward trend unrelated to the FTA.

Figure 6

Secular Growth

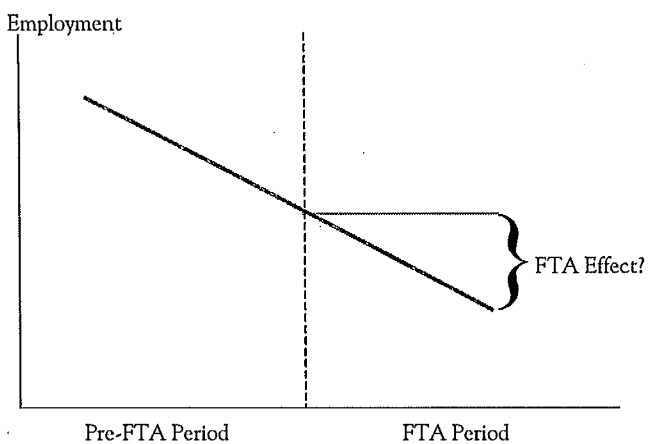


TABLE 3

HIGHLY IMPACTED INDUSTRIES DISPLAYING SECULAR BEHAVIOUR (FIGURE 6)

	EMPLOYMENT GROWTH, FTA PERIOD (Δy_{i1})	EMPLOYMENT GROWTH, PRE-FTA PERIOD (Δy_{i0})	TARIFF CUT, FTA PERIOD ($-\Delta\tau_{i1}^{FTA}$)
	(PERCENTAGE RATE)		
Women's Blouse and Shirt Industry	-17	-19	9
Women's Dress Industry	-12	-6	16
Women's Coat and Jacket Industry	-10	-10	16
Shipbuilding and Repair Industry	-8	-8	24
Men's and Boys' Coat Industry	-6	-6	14

Notes: Industries are defined at the 4-digit SIC level. For Δy_{i1} and $\Delta\tau_{i1}^{FTA}$, changes are over 1988-96. For Δy_{i0}, changes are over 1980-86.

If all the industries that experienced deep tariff cuts just happened to look like our Figure 6 industry, then we would mistakenly attribute employment losses to the FTA. What makes this possibility worrisome is that there is every reason to think that Figure 6 is representative. Sluggish growth or even decline is an important factor determining an industry's ability to lobby successfully for protection. This political economy effect is well documented (e.g. Trefler 1993). Thus, industries that declined in the pre-FTA period likely had high tariffs in 1988 and hence deep FTA-period tariff cuts. Table 3 provides examples of these industries.

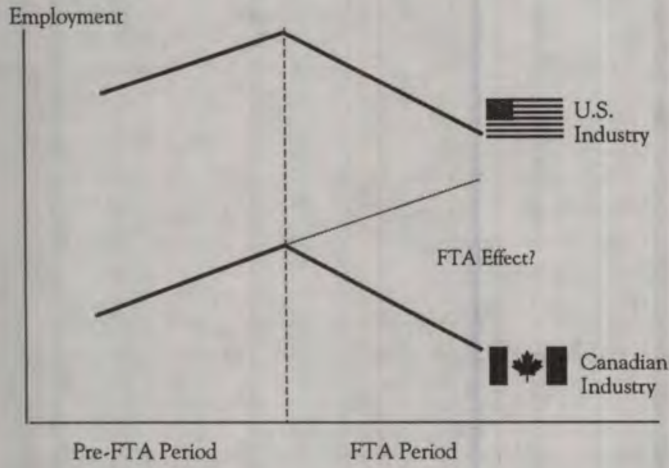
To prevent secular growth trends from being imputed to the FTA tariff cuts, we introduce a growth fixed effect, α_i, into Equation (3). As a result, our analysis only picks up growth effects that are departures from trend growth. This is important: The aggregate time-series trends in employment and labour productivity that underlie the analysis of the second section will be irrelevant in the following econometric analysis.

TAKING INTO CONSIDERATION IDIOSYNCRATIC SHOCKS (Δy_{is}^{US})

FIGURE 7 ILLUSTRATES A DIFFERENT TYPE OF PROBLEM, one that arises from putting too much stock in secular trends. In the fictitious Canadian industry illustrated in Figure 7, there is employment growth up to the implementation of the FTA and a decline afterwards. The secular trend argument of Figure 6 leads one to think that, in the absence of the FTA, the industry would have continued growing at a rate given by the grey line. That is, the difference

FIGURE 7

IDIOSYNCRATIC SHOCKS



between the Canadian and grey line would be viewed as employment losses attributable to the FTA. Now consider the top line in Figure 7, which shows the U.S. counterpart of our fictitious Canadian industry. This fictitious U.S. industry takes a sharp employment hit during the FTA period. This may be due to technical change that made its product obsolete or to new competition from Korea, or to one of many other possible demand and supply shocks that were *idiosyncratic* to the industry during that period.

Examples of industries that behaved as in Figure 7 are common. Table 4 lists a number of such industries that belong to the highly impacted group. In each case, failure to control for idiosyncratic shocks would lead one to incorrectly attribute Canadian labour productivity gains to the FTA. To avoid this, we control for idiosyncratic supply and/or demand changes by introducing a U.S. control variable, Δy_{is}^{US}, into the regression of Equation (3). Δy_{is}^{US} is the U.S. counterpart to Δy_{is}. For example, if Δy_{is} is Canadian employment growth, Δy_{is}^{US} is U.S. employment growth. Trefler (2001) examines the endogeneity of Δy_{i1}^{US} and provides abundant evidence that endogeneity is not empirically important.

TABLE 4

HIGHLY IMPACTED INDUSTRIES DISPLAYING IDIOSYNCRATIC BEHAVIOUR (FIGURE 7)

	CANADIAN LABOUR PRODUCTIVITY GROWTH, FTA PERIOD (Δy_{i1})	U.S. LABOUR PRODUCTIVITY GROWTH, FTA PERIOD (Δy_{i1}^{US})	CANADIAN LABOUR PRODUCTIVITY GROWTH, PRE-FTA PERIOD (Δy_{i0})	TARIFF CUT, FTA PERIOD ($-\Delta\tau_{i1}^{FTA}$)
	(PERCENTAGE RATE)			
Fur Goods Industry	-15	-12	5	10
Luggage and Handbag Ind.	-8	-9	0	8
Footwear Industry	-8	-8	1	13
Children's Clothing Ind.	-7	-10	2	16
Other Clothing and Apparel Industry	-5	-4	3	10
Sweater Industry	-5	-9	6	16
Other Office Furniture Ind.	-1	-3	10	9

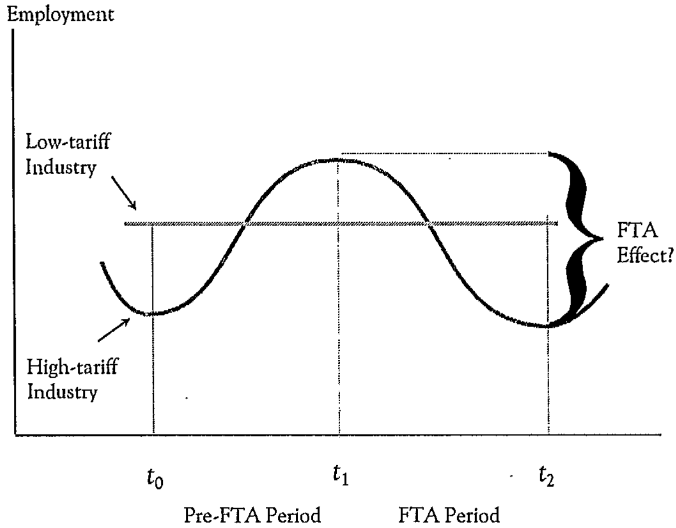
Notes: Industries are defined at the 4-digit SIC level. For Δy_{i1}, Δy_{i1}^{US} and $\Delta\tau_{i1}^{FTA}$, changes are over 1988-96. For Δy_{i0}, changes are over 1980-86.

CYCLICALITY AND BUSINESS CONDITIONS (ΔZ_s)

A KEY ISSUE IN EXAMINING THE FTA is the treatment of the early 1990s recession. The recession started in 1989 and GDP did not recover to 1988 levels until 1993. A major problem arises from the fact that industries differ both in terms of their sensitivity to business cycles and in terms of the peak-to-peak timing of their cycles. Figure 8 illustrates the problem using two fictitious industries. To make matters as clear as possible, our fictitious low-tariff industry features no cyclicality and is represented by a straight line in Figure 8. In contrast, our Figure 8 high-tariff industry is cyclical. Suppose that we examine employment changes over the period going from t_1 to t_2. We would observe no employment losses in the low-tariff industry and large employment losses in the high-tariff industry. However, if we compared year t_2 with a comparable point on the pre-FTA business cycle (i.e. year t_0), a different conclusion emerges. Again, to keep things simple, we have drawn Figure 8 so that employment is down by the same amount at both t_0 and t_2. In this case, the correct inference is thus that the FTA had no impact.

FIGURE 8

CYCLICALITY AND BUSINESS CONDITIONS



In practice, as opposed to our fictitious example, it is not possible to guess at the direction of bias introduced by cyclicality. The main message is only that one must control for cyclicality. General business conditions can be introduced into Equation (3) by including a regressor $\Delta z_s(t)$ that measures movements in GDP, the exchange rate, Canada-U.S. interest rate differentials, and other macro variables. The s subscript indexes the period while the t argument indexes the number of years into the period. $\Delta z_s(t)$ has no industry subscript. However, the impact of these macro variables will vary from industry to industry. Thus, in Equation (3), $\Delta z_s(t)$ has a coefficient, δ_i, that varies across industries.

DOUBLE DIFFERENCING

WE HAVE NOW FINISHED EXPLAINING EQUATION (3). We repeat it here for reference. For each t,

$$(4)\quad \Delta y_{is}(t)=\alpha_i+\alpha_s+\beta\Delta\tau_{is}^{FTA}(t)+\gamma\,\Delta y_{is}^{US}(t)+\delta_i\Delta z_s(t)+\varepsilon_{is},$$
$$s = 0, 1 \text{ and } i = 1, \ldots, N.$$

With N industries and 2 periods, there are $2N$ observations. However, there are $2N + 4$ parameters for each t.[5] To eliminate the α_i, we follow the usual approach of differencing across periods. Further, by judicious choice of t's, we can also eliminate the $\delta_i \Delta z_s(t)$. The argument is as follows.

From Table 5, one can see that the 1980-86 and 1988-96 periods had many common elements. The start year of each was the end year of a prolonged expansion. The second year of each ushered in a deep recession that reduced manufacturing GDP by 10 percent. The major difference between the two recessions is in their length. After these recessions, GDP growth was similar in both periods. Since our sample ends in 1996, this means that GDP growth was similar over the 1983-86 and 1993-96 periods.

The upshot of all of this is that we have identified common periods in the two business cycles. These are shown in panel B of Table 5. First, 1980 and 1988 were comparable points on the two cycles. Second, $1980+t-2$ and $1988+t$ (for $t = 5, 6, 7, 8$) were comparable points on the two cycles. It follows that $\Delta z_1(t) = \Delta z_0(t-2)$ for $t = 5, 6, 7, 8$.

If we now difference Equation (4) across periods, we obtain:

$$(5) \quad \left(\Delta y_{i1}(t) - \Delta y_{i0}(t-2)\right) = \alpha + \beta \Delta \tau_{i1}^{FTA}(t) + \gamma\left(\Delta y_{i1}^{US}(t) - \Delta y_{i0}^{US}(t-2)\right) + \upsilon_i$$
$$t = 5, 6, 7, 8 \text{ and } i = 1, \ldots, N.$$

TABLE 5

MATCHING THE BUSINESS CYCLE

PRE-FTA PERIOD	FTA PERIOD	
PANEL A – COMPARISON ACROSS PERIODS		
1980	1988	Year of robust growth
1981	1989	Peak of the business cycle
1982	1990-92	Deep recessions Manufacturing GDP off by 10% in both periods
1983-86	1993-96	Expansionary periods Manufacturing GDP growth similar in both periods
PANEL B – YEAR-BY-YEAR MATCH		
1980-83	1989-93	
1980-84	1989-94	
1980-85	1989-95	
1980-86	1989-96	

Note: The FTA was implemented on January 1, 1989. The year 1988 appears in the FTA-period column because it is used as the base year for calculating FTA-period changes.

where $\alpha \equiv \alpha_1 - \alpha_0$ and we have used the fact that $\Delta\tau_{i0}^{FTA}(t) = 0$. In words, by a judicious choice of periods, we have placed industries at about the same point on the business cycle in each of the two periods. In this way, the pre-FTA period data on each industry's business cycle sensitivity has been used to control for its FTA-period cyclical sensitivity.

An examination of Equation (5) reveals that we have eliminated all but three unknown parameters: α, β, and γ. At the same time, we have controlled for secular trends, idiosyncratic demand and supply shocks, and differential business cycle sensitivity. Equation (5) is far more complex than its parsimonious specification suggests. It is our estimating equation.[6]

DATA

A WORD ABOUT THE DATABASE. It spans the years 1980-96 and combines detailed industry data from a large number of disparate sources. Canadian data come from Statistics Canada (1996). The variables include: imports and tariff duties from special tabulations of the International Trade Division; employment of all workers, hours worked by production workers, and value added in production activities, from special tabulations by the Canadian Annual Survey of Manufactures (ASM) Section; output deflators from the Input-Output Division and the Prices Division; and concordances from U.S. SIC (1987) and Canadian SIC (1970) to Canadian SIC (1980), from the Standards Division. Most of the U.S. data come from the National Bureau of Economic Research (NBER) Manufacturing Productivity Database (Bartelsman and Gray, 1996). See Trefler (2001) for details.

A key issue has to do with the measurement of productivity. It would be ideal to look at total factor productivity (TFP) using detailed 4-digit SIC data. Unfortunately, the Canadian ASM does not record the capital stock or investment information necessary for calculating 4-digit SIC-level TFP. We must thus use labour productivity, i.e. value added per unit of labour.

There are two other issues. First, it is better to measure labour by hours worked rather than by employment. But such information is available for production workers only. Recall that the Canadian data distinguish between workers employed in manufacturing activities and non-manufacturing activities. We have been referring to these as production and non-production workers since that distinction broadly follows the one used in the U.S. ASM. We therefore define labour productivity as value added in production activities divided by hours worked in production activities. As Trefler (2001) shows, our results are robust to redefining labour productivity as value added in all activities divided by total employment. Second, value added must be deflated. We use output deflators rather than the preferred, but unavailable, value-added deflators. Trefler (2001) provides some evidence at the 2-digit SIC level that this does not matter for the purposes at hand. Finally, there are a number of other more standard issues to be dealt with; these are described in Trefler (2001). One issue not dealt with here has to do with the treatment of purchased services. This issue is discussed in Appendix A.

FINDINGS – PRODUCTIVITY GROWTH AND EMPLOYMENT LOSSES

LABOUR PRODUCTIVITY

TABLE 6 REPORTS THE ESTIMATES OF EQUATION (5) for labour productivity. There are three parameters: α, which is the intercept, β, which is the coefficient on $\Delta\tau_{i1}^{FTA}(t)$, and γ, which is the coefficient on $\Delta y_{i1}^{US}(t)-\Delta y_{i0}^{US}(t-2)$. The parameter of interest is β, which gives the impact of tariff cuts on labour productivity. Each row corresponds to a different end-point of the pre-FTA and FTA periods, i.e. up to a different t. For example, row 1 corresponds to pre-FTA changes over 1980-86 and FTA changes over 1988-96. This is the longest horizon we can consider because 1996 is the last year for which data is available. Row 4 corresponds to pre-FTA period changes over 1980-83 and FTA changes over 1988-93. This is the shortest horizon that we can properly consider because of the timing of the two business cycles. See Table 5 for further details.

Rows 1 to 4 of Table 6 provide a strong sense of the timing of the labour productivity effects. The outstanding feature is that the estimated β rise and their standard errors fall as the FTA-period horizon is pushed from 1993 to 1996. That is, the impact on labour productivity of a given tariff cut strengthens as the adjustment period lengthens.

It would be nice to extend the analysis back to the early years of the FTA, before any significant adjustment period had elapsed. In other words, it would be interesting to consider the effects on labour productivity for horizons ending in 1990, 1991, and 1992. As discussed earlier, this is not possible because of business cycle timing issues. Indeed, for this reason, we did not even collect the 1981-82 data that would have allowed for a crude examination of this issue. This said, a very rudimentary but feasible approach for 1992 is to match the 1989-92 and 1980-84 periods (row 5 of Table 6). Likewise, a very crude approach for 1991 is to match the 1989-91 and 1980-83 periods (row 6). The results presented in Table 6 show that the estimated β do fit the pattern described above: the coefficient grows as the time horizon is lengthened.

Trefler (2001) only reports the results for a single specification, which is similar to that of row 1 of Table 6. This is because he was not interested in the timing issues that are at the heart of our own study. Also, Trefler's results corresponding to row 1 are slightly different, reflecting the fact that, unlike him,

TABLE 6

REGRESSION ESTIMATES FOR LABOUR PRODUCTIVITY

Row	FTA Period Horizon	$\Delta\tau_{i1}^{FTA}(t)$ β	s.e.	$\Delta y_{i1}^{US}(t) - \Delta y_{i0}^{US}(t-2)$ γ	s.e.	Intercept α	s.e.	$\overline{R}^2$
1	1996	-1.56**	0.49	0.32**	0.09	0.01*	0.00	0.09
2	1995	-1.43**	0.52	0.15	0.10	0.00	0.00	0.04
3	1994	-1.32*	0.54	-0.04	0.10	-0.01	0.01	0.02
4	1993	-0.79	0.64	-0.15	0.11	0.00	0.01	0.01
5	1992	-0.75*	0.34	0.17	0.12	0.00	0.01	0.02
6	1991	-0.59	0.62	0.04	0.12	-0.01	0.01	-0.01

Notes: Regression estimates of equation (5). There are 202 observations; s.e.: standard error.
The FTA period horizon is the end year chosen for the FTA period. See Table 5 for details.
* and ** indicate statistical significance at the 5% and the 1% levels, respectively.

we omitted the nine 4-digit SIC industries making up the automotive sector. Finally, Trefler (2001) considers a considerable number of specification checks. We have examined all of these checks only to arrive at the same conclusion as: our estimates are robust to a wide variety of alternative specifications.

We are interested in the timing of the labour productivity impacts. This is not completely answered by our estimated β. For one, β is an elasticity whereas we are interested in the total impact. For another, even if β were constant over time, the FTA impact would progressively rise because the size of the tariff cut deepens as the FTA horizon lengthens. To obtain the impact of the FTA on labour productivity we need two definitions. Let *Observed Change* be the log or percentage change in labour productivity over the first t years of the FTA period. The percentage change is calculated as the weighted average of the percentage changes observed in each industry. The weights used are the industry's share of value added in production activities (the numerator of labour productivity). Let *Change Due to FTA* be the log or percentage change in labour productivity estimated to be caused by the FTA. Appendix B provides exact formulas for *Observed Change* and *Change Due to FTA*.

The top and bottom panels of Table 7 report *Change Due to FTA* and *Observed Change*, respectively, for different values of the time horizon, t. Consider first the *All Industries* column. The FTA had raised labour productivity by 1.1 percent as of 1991, by 2.6 percent as of 1993, and by 4.7 percent as of 1996. Further, these figures rise at each time horizon t, indicating that the productivity benefits of the FTA have not plateaued. The results are even more striking when one considers the highly impacted industries (those with tariff cuts in excess of 8 percent over 1988-96). For this group, the FTA had raised labour productivity

TABLE 7

LABOUR PRODUCTIVITY IMPACTS OF THE FTA

TIME HORIZON	β	ALL INDUSTRIES	HIGHLY IMPACTED INDUSTRIES	MODERATELY IMPACTED INDUSTRIES	LIGHTLY IMPACTED INDUSTRIES	NON-IMPACTED INDUSTRIES
			CHANGE DUE TO FTA (%)			
1988-96	-1.56	4.7	26	9	4	-1
1988-95	-1.43	4.5	22	8	4	-1
1988-94	-1.32	4.3	17	8	4	1
1988-93	-0.79	2.6	11	4	2	0
1988-92	-0.75	2.3	13	3	2	0
1988-91	-0.59	1.1	5	2	1	0
			OBSERVED CHANGE (%)			
1988-96		20	28	16	25	18
1988-95		17	25	10	19	17
1988-94		16	23	8	19	15
1988-93		9	19	4	16	5
1988-92		2	16	1	6	-2
1988-91		-2	12	-3	1	-6
$\Delta\tau_{ii}^{FTA}$			> 8	> 4	> 1	< 1
Number of observations			34	51	56	72

by 5 percent as of 1991, by 11 percent as of 1993, and by an extraordinary 26 percent as of 1996. Further, the increase in the productivity gains shows no sign of abating.

In this study, we implicitly compare several hypotheses. The first states that because of agglomeration economies, all productivity gains from the FTA flow to the United States. This is obviously incorrect. The second states that there are productivity gains, but that these are small and come only after a long period of incubation. This is also incorrect. Table 7 shows that the labour productivity effects of the FTA were enormous, arrived quickly, and continue to accrue.

A NOTE ON THE SIZE OF LABOUR PRODUCTIVITY GAINS

FROM THE *OBSERVED CHANGE* PANEL OF TABLE 7, we can see that the FTA labour productivity effect has been a major contributor to rising productivity. For example, the FTA explains 4.7 percentage points of the 20 percentage point increase in labour productivity experienced by all of manufacturing as of 1996. That is, manufacturing experienced substantial productivity benefits in the FTA period, about one quarter of which are due to the FTA.

This 4.7 percent labour productivity effect is large when we consider that most industries had very low tariffs going into the FTA. The average tariff cut was only 4.5 percent. For highly impacted industries, the FTA-induced productivity gains by 1996 were a huge 26 percentage points and account for almost all of the productivity gains in those industries.

Finally, it is helpful to present the 1996 productivity gains on an annual basis as they are then expressed in units comparable to more familiar indicators such as GDP growth. Since we are working in log changes, the numbers can be put into compound annual changes simply by dividing by 8. For all of manufacturing, the FTA tariff concessions raised labour productivity by 0.6 percent per year. For highly impacted industries, the tariff concessions raised labour productivity by 3.3 percent per year. These are enormous changes, large enough to wipe out differences between Canadian and U.S. productivity growth. We find it amazing that a government policy could be so effective in raising labour productivity.

EMPLOYMENT

TABLE 8 REPORTS THE ESTIMATES OF EQUATION (5) for employment and for various time horizons t. The coefficient β on $\Delta\tau_{i1}^{FTA}(t)$ is statistically significant for almost every t, indicating that the FTA-mandated tariff cuts reduced employment. Most interesting for our purposes is the time profile of these employment reductions. Table 8 shows that the estimated β increase only up to 1994. That is, the impact of a given tariff cut diminishes after 1994 as the sector adjusts.

As before, one must distinguish between the impact for a *given* tariff cut (i.e. β) and the change due to the FTA as tariffs were cut year after year. Table 9 provides information on *Change Due to FTA* and on *Observed Change*. From the *All Industries* column, we can see that the FTA had reduced employment by 1.3 percent as of 1991, by a peak 6.4 percent as of 1994, and by 5.3 percent as of 1996. The evidence is quite clear that the employment losses have already peaked. This is as true for all of manufacturing and for each group of industries. For example, the highly impacted industries had lost an incredible 21 percent of their employment by 1994. This was vividly shown earlier in Figure 1.

The size of these employment losses is alarming. The bottom panel of Table 9 indicates that the FTA-induced employment losses account for a third of all lost jobs as of 1996. It is of some interest, though, that these employment losses do not explain all of the employment losses in the highly impacted industries. Early on, in 1992, these industries had taken a big employment hit that appears to have been independent of the FTA. This casts doubt on whether the recession was induced by the FTA.

TABLE 8

REGRESSION ESTIMATES FOR EMPLOYMENT GROWTH

Row	FTA Period Horizon	$\Delta\tau_{i1}^{FTA}(t)$ β	s.e.	$\Delta y_{i1}^{US}(t) - \Delta y_{i0}^{US}(t-2)$ γ	s.e.	Intercept α	s.e.	$\bar{R}^2$
1	1996	1.57**	0.55	0.20*	0.08	-0.01**	0.00	0.08
2	1995	1.76**	0.55	0.22**	0.08	-0.01	0.01	0.10
3	1994	1.75**	0.59	0.22**	0.08	0.00	0.01	0.08
4	1993	1.21*	0.62	0.27**	0.07	0.00	0.01	0.09
5	1992	0.99**	0.34	0.21*	0.08	-0.02**	0.01	0.07
6	1991	0.66	0.59	0.24**	0.07	-0.01	0.01	0.05

Notes: Regression estimates of Equation (5). There are 204 observations; s.e.: standard error. The FTA period horizon is the end year chosen for the FTA period. See Table 5 for details. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

TABLE 9

EMPLOYMENT IMPACTS OF THE FTA

Time Horizon	β	All Industries	Highly Impacted Industries	Moderately Impacted Industries	Lightly Impacted Industries	Non-impacted Industries
			Change Due to FTA (%)			
1988-96	1.57	-5.3	-22	-9	-4	1
1988-95	1.76	-6.0	-22	-10	-5	0
1988-94	1.75	-6.4	-21	-10	-6	-1
1988-93	1.21	-4.2	-14	-7	-4	-1
1988-92	0.99	-2.8	-10	-4	-2	0
1988-91	0.66	-1.3	-4	-2	-1	0
			Observed Change (%)			
1988-96		-16	-36	-20	-16	-8
1988-95		-15	-33	-18	-15	-7
1988-94		-17	-32	-18	-18	-11
1988-93		-18	-30	-18	-20	-14
1988-92		-17	-29	-15	-23	-11
1988-91		-13	-21	-9	-19	-9
$\Delta\tau_{i1}^{FTA}$			> 8	> 4	> 1	< 1
Number of observations			34	51	56	72

To summarize, the industries that were heavily impacted by the FTA suffered staggering employment losses. Further, the timing of these losses was not straightforward: most of the losses came after the recession (i.e. after 1992) and by 1994 these losses had peaked.

General Equilibrium Considerations

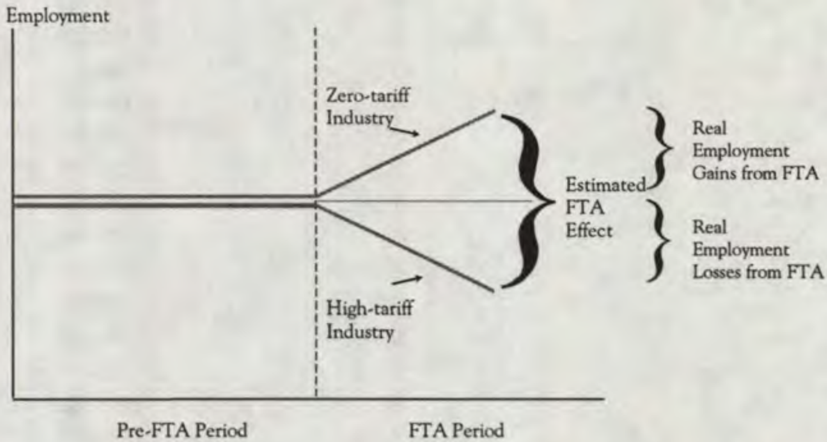
A MAJOR LIMITATION OF THIS STUDY is that it does not take into account the general equilibrium interactions between industries. These interactions are the primary channels through which international trade is expected to affect domestic economies. In the standard trade model, tariff reductions lead to a reallocation of employment from the least competitive to the most competitive sectors. This mechanism cannot be captured by our methodology. Indeed, it is not easily or obviously captured by any known methodology.

However, we can determine the sign of the bias associated with this elusive general equilibrium effect. Consider employment in Figure 9. The top line plots employment for some fictitious industry that had zero tariffs going into the FTA period. The bottom line plots employment for some fictitious industry that lost employment as a result of FTA-mandated tariff cuts. Our methodology implicitly compares the performance of the two industries and attributes the difference to the FTA. (*Estimated FTA Effect*, in Figure 9.) However, a different interpretation is that the FTA shifted employment out of the less-competitive industry (the high-tariff industry) and into the more-competitive industry (the zero-tariff industry). In this case, the FTA induced employment losses in one industry, employment gains in the other, and only modest net employment losses.

Is there any evidence of this possibility? Between 1988 and 2000, U.S. manufacturing employment contracted by 4.4 percent. Using this as a benchmark, we expect Canadian manufacturing to have also contracted by 4.4 percent. In fact, it expanded by 0.7 percent — Canadian manufacturing growth did 5.1 percentage points better than its U.S. counterpart. Similar conclusions emerge from the spotty data available on manufacturing employment in other countries. The International Labour Organization has a project aimed at putting manufacturing employment data on a consistent basis across countries and over time. The available data are limited: the most recent year is 1994 and Canada is absent from the sample. Table 10 reports the compound annual rates of change in manufacturing employment for all countries included in that project. (For reference, Canada has been added to the table.) The data presented in Table 10 places Canadian manufacturing employment growth in a favourable light. Among the G-8 countries listed in Table 10, Canada has the best performance. Indeed, most countries experienced significant employment contractions.

FIGURE 9

GENERAL EQUILIBRIUM EFFECTS



This leads us to believe that the FTA did not reduce employment in Canadian manufacturing. Rather, the FTA induced a shift of employment from high-tariff industries to low-tariff industries, just as predicted by trade theory. Nevertheless, the large employment losses in high-tariff industries are indicative of the large transition costs associated with moving out of low-end, heavily protected industries and into high-end, competitive industries.

We next turn to productivity. Our results suggest that the FTA induced productivity growth *within* industries. However, the results say nothing about the general equilibrium impact of the FTA on aggregate productivity. From Table 2, we know that the highly impacted industries tend to have below-average labour productivity. If the FTA shifted output away from these industries and towards less-impacted, high-productivity industries, then it should have raised labour productivity in a way not captured by our results.

We can analyze this imperfectly by asking whether the FTA period witnessed a rise in the between-industry component of productivity growth. In fact, there has been no such trend. During a period where productivity grew by 20 percent (see Table 7), the between-industry component of productivity growth was effectively 0 percent at each time horizon *t*. Thus, we have the surprising and puzzling result that the FTA re-allocated labour out of low-productivity industries and into high-productivity industries, but that this shift did not contribute to rising productivity.

TABLE 10

COMPOUND ANNUAL CHANGE IN MANUFACTURING EMPLOYMENT

COUNTRY	EMPLOYMENT CHANGE (%)	PERIOD
Hong Kong	-7.1	1988-94
Germany	-6.1	1991-94
Finland	-5.7	1989-94
Sweden	-4.6	1988-94
Spain	-2.1	1988-94
France	-1.8	1988-94
Norway	-1.8	1988-94
Australia	-1.8	1988-93
United States	-1.7	1988-93
Korea	-0.8	1990-94
Japan	0.5	1988-94
New Zealand	0.5	1988-94
Canada	0.7	1988-2000
Turkey	0.8	1989-93
Netherlands	1.2	1988-92
Portugal	1.4	1988-91
Singapore	1.5	1988-94
Philippines	2.4	1988-94
Indonesia	9.9	1988-94

Source: International Labour Office. "ILO-Comparable Annual Employment and Unemployment Estimates (No. 6)," *Bulletin of Labour Statistics*, 1996-2, pp. XI-XLVI.
Canadian data are not available from this source. Instead, CANSIM data have been used.

CONCLUSIONS

WHAT ARE OUR MAIN FINDINGS? Our estimates show that between 1988 and 1996, the FTA reduced employment by 5 percent in manufacturing as a whole and by 22 percent in manufacturing industries that experienced the deepest cuts. On the other hand, the FTA raised manufacturing labour productivity by 5 percent and, in industries that experienced the deepest cuts, by a remarkable 26 percent. These numbers would seem to suggest that the FTA involved heavy employment adjustment costs and huge productivity benefits. This study addresses two issues raised by these costs and benefits. First, there is the timing of these employment losses. We offer strong evidence that the employment losses were both temporary and concentrated early on. That they were concentrated early on is crystal clear from Figure 1: employment losses had peaked, or at least plateaued, by 1994. That the employment losses were not permanent is less clear. However, the fact that the Canadian manufacturing sector has returned to its 1988 employment level, whereas the manufacturing sectors of the United States and other G-8 countries have not suggests to us that the FTA had no net employment effects. Of course, this is not meant to minimize the adjustment costs borne by labour as the FTA shifted employment out of low-end, high-tariff industries and into high-end, low-tariff industries.

Second, there is a question about the *net* benefits accruing from the FTA. With discounting, the more front-ended are the employment costs relative to the productivity benefits, the lower are the net benefits from the FTA. Thus, we need to know the timing of the costs and benefits before we can properly past judgement on the achievements of the FTA. As shown in Figure 1, these costs and benefits accrued at roughly the same rate. For the highly impacted industries especially, there is no sense in which the employment costs were front-ended relative to the productivity gains. Thus, any assessment of the FTA must be independent of the discount rate used. It should focus instead on winners and losers — on those workers and industries that bore the brunt of the short-run employment losses *versus* those workers, industries, and consumers that garnered the benefits of long-run productivity gains.

Without in any way denigrating the employment losses, we conclude by focussing on the productivity gains. The reason is simple. Despite the many claims about the productivity benefits of freer trade, the econometric evidence is entirely unpersuasive. Our work thus fills an important gap in the literature. This study implicitly compares several hypotheses. The first states that because of agglomeration economies, all productivity gains from the FTA flow to the United States. We show this to be incorrect. The second states that there are productivity gains, but that these are small and come only after a long period of incubation. We also show that this is incorrect. In fact, we show that the FTA induced enormous labour productivity gains. Further, these gains arrived quickly and continue to accrue. This finding is an important contribution to discussions concerning the net benefits of tariff concessions – discussions that are bound to be revisited as we debate the merits of a Free Trade Area of the Americas.

ENDNOTES

1 The analysis for all of manufacturing is trickier since, as we will discuss in the next paragraph, the employment losses plotted in the bottom panel of Figure 1 are overstated.

2 These numbers differ from the 15 percent reduction in employment and the 17 percent increase in productivity cited in Trefler (2001). The difference is one of definition rather than substance. In Trefler (2001), the numbers refer to the group of 71 industries with tariff cuts in excess of 5 percent. In our study, the numbers refer to the more narrowly focused group of 34 industries with tariff cuts in excess of 8 percent. These industries experienced deeper cuts and hence larger FTA impacts.

3 The FTA period is 1989-96. Changes over the FTA period are percentage changes using 1988 as the base year. Thus, even though the FTA period is 1989-96, we sometimes write 1988-96 as the FTA period in order to emphasize the use of 1988 as the base year.

4 Data are from CANSIM matrix L97800.

5 The $2N$ parameters are the α_i and the δ_i. The 4 parameters are β, γ, and the α_s for $s = 0, 1$. Note that all parameters should be indexed by t. We forgo this additional notation.

6 We will not discuss the issue of the endogeneity of tariffs. For all the specifications we report, we have tested for endogeneity using a Hausman test. In every case, endogeneity is rejected. Details of the endogeneity test appear in Trefler (2001).

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APPENDIX A

A DATA ISSUE RELATED TO LABOUR PRODUCTIVITY

WE SAW THAT THERE ARE DATA LIMITATIONS preventing us from using a TFP definition of productivity. But there are also a large number of data issues to be aware of when using definition of productivity based on labour productivity. Some of these are taken up in Trefler (2001). However, there is one other — the data problem created by benchmarking purchased services and the inclusion of purchased services in the definition of value added. In fact, this problem plagues all productivity research. Basically, firms do not report all purchased services in the ASM questionnaires of either country. Instead, the data are benchmarked using separate surveys. In Canada, the last survey is now 15 years old. Given that Canada invests more in timely input-output tables, we can only guess that the U.S. benchmark is even older. Benchmarking means that the measure of purchased service inputs in period t is $S_t = \sigma Q_t \varepsilon_t$, where Q_t is output, $\sigma = S_0/Q_0$ is the ratio of purchased services to output in the benchmark year, and ε_t is the benchmarking error. Using obvious notation and simplifying to avoid issues of chaining, deflation, and multiple inputs, let's define $TFP_t \equiv \ln Q_t - \alpha \ln X_t - \beta \ln S_t$, where X_t collects all non-service inputs. Then, the change in TFP_t is $\Delta TFP = \Delta \ln Q - \alpha \Delta \ln X - \beta \Delta \ln Q - \beta \Delta \ln \varepsilon$ and what researchers are reporting is not ΔTFP, but $\Delta TFP + \beta \Delta \ln \varepsilon$. Thus, sectoral TFP growth includes trends in the contracting out of services which benchmarking fails to pick up. This raises a number of important issues. Their relevance here depends on whether the $\Delta \ln \varepsilon$ are correlated with tariff cuts and, if so, whether the trends in $\Delta \ln \varepsilon$ are captured by our secular growth and idiosyncratic controls.

APPENDIX B

THE DEFINITION OF OBSERVED CHANGE AND CHANGE DUE TO FTA

LET I BE A GROUP OF INDUSTRIES, e.g. the highly impacted group. Recall that $Y_{i,1988}$ is the level of, say, productivity in industry i in 1988. The percentage change in the productivity of industry i over the first t years of the FTA period is given by $\Delta y_{i1}(t)t$, where $\Delta y_{i1}(t)$ is the average annual log or percentage change in productivity over the first t years of the FTA. The industry i change in productivity over the first t years of the FTA period is approximately $(\Delta y_{i1}(t)t)Y_{i,1988}$ — that is, the log or percentage change in the initial level times the initial level. The change in productivity among industries in any group I is approximately $\sum_{i\in I}\left(\Delta y_{i1}(t)\,t\right)Y_{i,1988}$. The percentage change in productivity is approximately $\sum_{i\in I}\left(\Delta y_{i1}(t)\,t\right)Y_{i,1988} / \sum_{j\in I} Y_{j,1988}$. This can be rewritten as:

$$\sum_{i\in I}\left(\Delta y_{i1}(t)\,t\right)\omega_i \text{ where } \omega_i \equiv Y_{i,1988} / \sum_{j\in I} Y_{j,1988}.$$

In the case of labour productivity, ω_i is industry i's share of value added in production activities, i.e. the numerator of labour productivity. Using the fact that $\hat{\beta}\Delta\tau_{i1}^{FTA}(t)$ is the prediction of the impact of tariff concessions, the predicted tariff-induced log change in productivity is $\sum_{i\in I}\hat{\beta}\Delta\tau_{i1}^{FTA}(t)\,t\,\omega_i$. We collect these observations in the following equations.

$$\textit{Observed Change in the first t years of the FTA period} \equiv \sum_{i\in I}\Delta y_{i1}(t)\,t\,\omega_i.$$

$$\textit{Change Due to FTA in the first t years of the FTA period} \equiv \sum_{i\in I}\hat{\beta}\Delta\tau_{i1}^{FTA}(t)\,t\,\omega_i.$$

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Industry Canada

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Are Canadian-controlled Manufacturing Firms Less Productive than their Foreign-controlled Counterparts?

SUMMARY

THE PURPOSE OF THIS PAPER is to analyse the multi-factor productivity (MFP) gap between Canadian- and foreign-controlled manufacturing firms. The evidence from micro (firm-level) data suggests that Canadian-controlled firms, on average, were 25 percent less productive than their foreign-controlled counterparts over the 1985-88 period. The MFP gap, however, narrowed to about 16 percent during the 1989-95 period. Labour quality, unionization, firm size, and industry dummies are significant determinants of inter-firm variations in productivity levels. However, they did not contribute to the MFP gap between Canadian- and foreign-controlled firms. In addition, contrary to popular perceptions, Canadian-controlled firms are not concentrated in low-productivity industries.

INTRODUCTION

THE DRAMATIC REDUCTION in transportation and communication costs and the intense international competition for markets, capital, and technology have considerably increased the globalization of business. The Canadian business community has taken an active part in this process: Canada's trade and investment orientation is more than twice the average of the other G-7 countries, and the gap has widened over the past 10 years. Today, exports account for more than 40 percent of Canada's gross domestic product (GDP), and imports play an equally significant role in the Canadian economy. Likewise, the shares of inward and outward foreign direct investment stocks in GDP have increased significantly in the past decade.

Recent research suggests that foreign direct investment, trade, and technology/knowledge flows complement each other (Gera, Gu, and Lee, 1999; McFetridge, 1998; Rao and Ahmad, 1996; Rao, Legault, and Ahmad, 1994). For example, intra-firm trade accounts for close to half of all trade flows between Canada and the United States. One in 10 jobs in Canada depends directly on inward foreign direct investment. Foreign-controlled companies contribute about half of all Canada's manufacturing output, and their share has been increasing over the past 10 years.

Despite this growing trade and investment orientation, Canada's productivity and real income performance has been lagging behind that of other members of the Organisation for Economic Co-operation and Development (OECD). More worryingly, the Canada-U.S. manufacturing labour productivity gap has widened considerably since 1985, and Canada's productivity level is below that of the United States in most manufacturing industries (at the two-digit level). This widening of the productivity gap is surprising and seems to be inconsistent with the rising trade and investment orientation: theoretical and empirical research to date strongly suggests that an increase in foreign direct investment (both inward and outward) leads to trade expansion, increases technology and knowledge exchange, and improves productivity in both host and home countries (McFetridge, 1998; Globerman, Ries, and Vertinsky, 1994; Corvari and Wisner, 1993).

As expected, Canada's weak productivity record in the 1990s has attracted considerable attention among policy makers, the media, and academics. Some observers have actually blamed freer trade and the growing trade and investment orientation of the Canadian economy for the widening of the Canada-U.S. manufacturing labour productivity gap. The main goal of this study, therefore, is to explore the role of foreign-controlled firms with respect to Canada's poor manufacturing productivity record. Using firm-level data, the paper examines the multi-factor productivity (MFP) performance of foreign- and Canadian-controlled firms and tries to answer the following important research questions:

- Are foreign-controlled manufacturing firms more (or less) productive than Canadian-controlled ones?
- Did the productivity gap widen (or narrow) during the 1990s?
- What factors explain (or do not explain) the difference in productivity performance?

The paper is complementary to work by Globerman, Ries, and Vertinsky (1994, hereafter referred to as GRV), and Corvari and Wisner (1993, hereafter CW). GRV compare the economic performance of Canadian- and foreign-controlled establishments, using Statistics Canada's Censuses of Manufacturing, Mines and Logging for 1986. They show that foreign affiliates had significantly higher value-added per worker but that this difference vanished once factors such as size and capital intensity were taken into account.[1] Using industry-level data, CW also arrived at the conclusion that foreign-controlled establishments had a higher value-added labour productivity level than domestic-controlled establishments. They used labour intensity, labour quality, energy intensity, and R&D intensity, among others, in their attempts to explain the gap, but found that only energy intensity played a role in that regard.[2]

To some extent, our paper is also complementary to a more recent study by Baldwin and Dhaliwal (1998, hereafter BD). These authors examine labour productivity differences between domestic and foreign-controlled firms in the Canadian manufacturing sector, using the micro-economic establishments data collected in the Canadian Census of Manufacturers for the period 1973-93. Their analysis shows that Canadian-controlled manufacturing firms in different size and growth groups lagged behind their foreign-controlled counterparts in labour productivity growth.

Our study differs from BD, GRV, and CW on several aspects. First, we focus on multi-factor productivity measures rather than on partial productivity measures such as labour productivity. Second, we examine the impact of labour quality, firm vintage, export orientation, unionization, firm size, and industrial structure on inter-firm variations in productivity levels, and the productivity level gap between Canadian- and foreign-controlled firms.[3] Third, we use micro, firm-level data covering a period of 11 years.[4] The panel data on companies enable us to better capture firm-specific characteristics than do industry-level data, and to monitor productivity movements over time. In addition, our data are more up-to-date than those used by the other analysts.

Our research shows that, on average, Canadian-controlled manufacturing firms were 25 percent less productive than foreign-controlled firms during the 1985-88 period. The gap in MFP levels, however, narrowed to 16 percent over the 1989-95 period. Differences in labour quality, firm vintage, unionization, export orientation, firm size, and industrial structure were not responsible for the superior productivity performance of foreign-controlled firms. Rather, differences in technological know-how and managerial strategies may have accounted for the productivity gap. These results imply that foreign ownership is not responsible for the widening of the Canada-U.S. productivity gap in manufacturing. On the contrary, our results suggest that without the greater foreign direct investment orientation, the gap would have been wider.

The remainder of the paper is organized as follows. In the section entitled *Determinants of the Productivity Differences*, we identify five key determinants of productivity efficiency. In the section entitled *Empirical Framework*, we outline an empirical framework for productivity level comparisons. The section entitled

Empirical Analysis describes the characteristics of the manufacturing firms in our sample and discusses the regression results on the determinants of productivity performance of foreign- and Canadian-controlled firms. The role of industrial structure in the productivity gap is examined in the next section. In our final section, we summarize the main findings of our research and discuss their possible implications.

Determinants of Productivity Differences

Many studies attempt to explain productivity differences via observed differences among countries with respect to the factors that drive productivity. For example, Englander and Gurney (1994) use aggregate cross-country data to investigate the determinants of productivity growth. They find that inter-country differences in education and R&D contribute to the differences in productivity growth among countries. Pilat (1996) shows that the degree of competition and the growth of R&D stocks are positively related to productivity growth. Van Ark and Pilat (1993) explain differences in labour productivity levels of manufacturing industries between Germany, Japan, and the United States in terms of differences in capital intensity, labour quality, and industrial structure. Globerman, Ries and Vertinsky (1994) show that the labour productivity level advantage of foreign-controlled firms is entirely the result of differences in average firm size and capital intensity. Corvari and Wisner (1993) use labour intensity and quality, as well as energy and R&D intensity, among other factors, in their efforts to explain the labour productivity gap between Canadian-controlled firms and their foreign-controlled counterparts. Among these variables, they find that only energy intensity played a significant role. Consequently, much of the gap was not explained by differences in those variables.

In summary, past empirical studies suggest that differences in labour quality, R&D, the degree of competition, firm size, industrial structure, investment, technological know-how, and the effectiveness of managerial practices play an important role in explaining labour productivity differences.

We have identified five factors to explain inter-firm differences in MFP levels in the two groups of manufacturing firms — namely, labour quality, firm vintage, unionization, export orientation, and firm size.[5] Labour quality will be positively associated with productivity since skilled workers are more efficient than unskilled workers in operating machines and raising productivity. In this study, we use the proportion of white-collar workers in total employment as a proxy for labour quality, because in general workers in these occupational groups have much higher skills than those in blue-collar occupational groups.

A priori, the effect of firm vintage (age) on productivity is ambiguous. Older firms tend to have more experience due to "learning-by-doing," as well as more established and efficient supply and distribution systems, factors that have a positive influence on productivity. On the other hand, old firms tend to be less flexible in their operations and are equipped with older capital stock,[6] which can have a negative impact on overall efficiency.

Trade unions clearly affect the distribution of profits, but their impact on productivity is not clear (Kuhn, 1998). They affect productivity through their influence on the production process. On the one hand, unions improve productivity by reducing labour turnover and by monitoring and putting pressure on management to continuously refine the firm's operations. On the other hand, unionization can have a negative influence on productivity as a result of strikes and lockouts. The empirical results on this issue are also mixed: Brown and Medoff (1978) and Clark (1980) found that unions have a positive influence on productivity, whereas Machin (1991) and Hoxby (1996) found the opposite.

All other things being equal, the export orientation variable should have a positive impact on MFP thanks to its influence on competition, innovation, and scale economies. Baily and Gersbach (1995) state that "the greater the exposure of an industry to best-practice methods, the closer it is to best-practice productivity." Pilat (1996), Nickell (1996), and Rao and Ahmad (1996) also show that productivity is positively related to outward orientation because of the increased exposure to global competition and best-practice methods.

Firm size is introduced to capture differences in technology and innovative capacity across firms of different sizes.[7] Firm size can exert two opposing influences on productivity. Larger firms tend to have access to a larger pool of technology and to benefit more from scale economies. On the other hand, they tend to be less flexible in their operations, which could have a negative impact on productivity. Overall, however, the positive influences are expected to outweigh the negative ones. To capture the size effects, we divide the sample firms into three size classes: small firms, with fewer than 100 employees; medium-size firms, with between 100 and 499 employees; and large firms, with 500 employees or more.

EMPIRICAL FRAMEWORK

WE ASSUME THAT EACH FIRM'S PRODUCTION ACTIVITY is characterized by the following Cobb-Douglas production function[8]:

$$(1)\quad Y = A(Z)K^{\alpha_K}L^{\alpha_L}M^{\alpha_M},$$

where Y is gross output, K is capital input, L is labour input, and M represents intermediate inputs. α_K, α_L and α_M are the elasticities of output with respect to K, L, and M, and A is the efficiency parameter. As discussed in the previous section, we assume that production efficiency is a function of Z variables: labour quality, firm vintage, unionization, export orientation, and firm size.

The log-linear form of Equation (1) is as follows:

$$(2)\quad \ln(Y) = \alpha_0 + \alpha_{P_2}P_2 + \alpha_{P_3}P_3 + \alpha_D D + \alpha_{D_2}D{\cdot}P_2 + \alpha_{D_3}D{\cdot}P_3 + \sum_i \alpha_{I_i}I_i + \alpha_Q \ln Q + \alpha_V \ln V + \alpha_U \ln U + \alpha_E E + \alpha_{S_2}S_2 + \alpha_{S_3}S_3 + \alpha_L \ln L + \alpha_K \ln K + \alpha_M \ln M,$$

where I_i is a dummy for industry i aimed at capturing industry-specific impacts on productivity;

P_2 and P_3 are dummies for the periods 1989-92 and 1993-95 respectively (1985-88 is the control group);[9]

D is an ownership dummy, equal to one for Canadian-controlled firms and zero otherwise;

Q denotes labour quality, proxied by the share of white-collar employees in total employment;

V denotes firm vintage (age);

U denotes unionization, equal to 1 for unionized firms and 0 otherwise;

E is the export orientation dummy, equal to one if the firm exports and zero otherwise;

S_2 and S_3 are firm-size dummies for medium-sized and large firms, respectively (small firms are the control group).

Using production function (2), we could compute the MFP level for each firm. However, we are interested in comparing the average productivity level of Canadian-controlled firms with that of foreign-controlled firms. Average MFP levels for the two groups can be calculated by assigning an equal weight to all firms. This scheme, unfortunately, tends to overestimate the contribution of small and medium-sized firms and to underestimate the contribution of large firms to the group's aggregate productivity level. We can overcome this problem by assigning different weights to firms of different sizes, using gross output shares as weights. For example, we define the firm average of variable X (in logarithm) for group i in sub-period t as:

$$\overline{\ln X_t^i} = \sum_{j=1}^{N_t^i} w_{jt}^i \ln(X_{jt}^i)\,.$$

N_t^i denotes the number of observations in group i in sub-period t, and w_{jt}^i denotes the gross-output share of observation j in group i in sub-period t. Note that

$$\sum_{j=1}^{N_t^i} w_{jt}^i = 1$$

for each group in each sub-period, so that $\overline{\ln X_t}^i$ is the weighted sum of logarithmic values of variable X for group i in sub-period t.

We first estimate the aggregate productivity gap between Canadian- and foreign-controlled firms in the manufacturing sector. We define the logarithmic MFP gap (without accounting for the differences in the Z variables) between the two sets of firms in sub-period t as the difference in their aggregate MFP levels:

$$(3) \quad \ln MFPG_t = \overline{\ln MFP_t}^C - \overline{\ln MFP_t}^F,$$

where $\overline{\ln MFP_t}^C$ and $\overline{\ln MFP_t}^F$ are the weighted sums of the logs of the MFP levels of Canadian- and foreign-controlled manufacturing firms. The logarithmic MFP level of firm j controlled by group i in sub-period t, $\ln MFP_{jt}^i$, is defined as

$$(4) \quad \ln MFP_{jt}^i = \ln(Y)_{jt}^i - \hat{\alpha}_L \ln(L)_{jt}^i - \hat{\alpha}_K \ln(K)_{jt}^i - \hat{\alpha}_M \ln(M)_{jt}^i .$$

The MFP gap is the residual and could not be explained by capital, labour, and intermediate inputs. In order to examine what factors contributed to the MFP gap, we arrange Equation (3) by using Equations (2) and (4) and alternatively present Equation (3) as

$$(5) \quad \ln MFPG_t = \hat{\alpha}_{Dt} + \sum_i \hat{\alpha}_{Z_i} \Delta\overline{\ln Z_{it}}, \text{ where}$$

$$\hat{\alpha}_{Dt} = \Delta\overline{\ln(Y)}_t - \sum_i \hat{\alpha}_{Z_i} \Delta\overline{\ln Z_{it}} - \hat{\alpha}_L \Delta\overline{\ln(L)}_t - \hat{\alpha}_K \Delta\overline{\ln(K)}_t - \hat{\alpha}_M \Delta\overline{\ln(M)}_t \text{ and}$$

$$\Delta\overline{\ln X_t} = \overline{\ln X_t}^C - \overline{\ln X_t}^F, \text{ for any variable } X.$$

The MFP gap consists of two terms. $\hat{\alpha}_{Dt}$ is the MFP gap after accounting for differences in the explanatory variables (Z) between the two sets of firms. The second term represents the contribution of the differences in Z variables to the MFP gap. The contribution of each explanatory variable Z_i is $\hat{\alpha}_{Z_i} \Delta\overline{\ln Z_i}$.

EMPIRICAL ANALYSIS

IN THIS SECTION, we present the empirical results of our investigation. First, we describe briefly the micro-data set used for the analysis.

DATA

THE DATA ON CANADIAN- AND FOREIGN-CONTROLLED FIRMS were compiled from a number of sources. The primary sources were the Compustat and Compact-Disclosure/Canada databases, supplemented by data from Micromedia's *Profile Canada*, *Moody's International*, Statistics Canada's *Inter-Corporate Ownership*, and the *Canadian Trade Index* of the Alliance of Manufacturers & Exporters Canada. All Canadian-based manufacturing firms for which financial data are available were selected.[10] A detailed description of data sources is contained in Appendix. Most of the sampled firms are publicly traded companies, listed either on the Canadian or the American stock exchanges. A firm is labelled as Canadian-controlled if it is ultimately controlled by Canadians; otherwise it is considered as foreign-controlled.[11]

After eliminating outliers, our sample consisted of 1179 and 631 observations for Canadian- and foreign-controlled manufacturing firms, respectively, over the 1985-95 period.[12] These firms were classified into 19 manufacturing industries (corresponding to the two-digit level of Statistics Canada) on the basis of the Standard Industrial Classification (SCI) code given to each firm in the databases. The average firm size, measured in terms of output and employment, for the two groups of firms in the three sub-periods is displayed in Table 1, which shows that the average size of foreign-controlled firms, measured by output, is significantly greater than that of Canadian-controlled firms. The opposite is true when size is measured by employment. These results imply that, on average, labour productivity (gross output per employee) of Canadian-controlled firms is considerably below that of their foreign-controlled counterparts. Table 2 shows that our sample firms cover more than 50 percent of the manufacturing sector gross output.

RESULTS

THE ESTIMATION RESULTS FROM EQUATION (2) are reported in column (I) of Table 3.[13] Several interesting observations emerge. First, Canadian-controlled firms lag behind foreign-controlled firms in the unexplained MFP, and that lag is statistically significant, as shown by the coefficient on the ownership dummy. Second, all of the explanatory variables (with the exception of firm vintage and export orientation) have a significant impact on productivity. As expected, labour quality is statistically significant and has a positive influence on productivity.

TABLE 1

NUMBER OF OBSERVATIONS AND AVERAGE SIZE OF FIRMS BY PERIOD AND FIRM GROUP

	CANADIAN-CONTROLLED			FOREIGN-CONTROLLED		
		AVERAGE SIZE			AVERAGE SIZE	
PERIOD	OBSERVATIONS	EMPLOYEES	OUTPUT*	OBSERVATIONS	EMPLOYEES	OUTPUT*
1985-88	278	7,637	1,045	141	5,982	1,941
1989-92	486	5,259	808	353	2,250	687
1993-95	415	4,130	763	137	3,404	1,368
1985-95	1,179	5,422	848	631	3,335	1,115

Note: * 1985$ millions.

TABLE 2

COVERAGE RATIOS*

YEAR	GROSS OUTPUT OF THE SAMPLE AS A % OF THE TOTAL GROSS OUTPUT OF THE MANUFACTURING SECTOR
1985	53.8
1986	52.2
1987	50.0
1988	54.9
1989	53.1
1990	55.5
1991	53.0
1992	66.2
1993	60.8
1994	57.1
1995	52.7

Note: * All nominal variables are deflated by the appropriate industry price deflators from Statistics Canada.

These findings are consistent with those of Corvari and Wisner (1993). The firm vintage variable has the expected positive sign but is statistically insignificant. The influence of unionization on productivity is negative and significant. The export orientation variable has the unexpected negative sign but is statistically insignificant. The estimation results also suggest that small firms are significantly less productive than large ones, a finding that is similar to those of Baldwin (1996) and Rao and Ahmad (1996). Third, industries such as electrical machinery and food and beverages are more productive than others, such as textiles and non-metallic mineral products — a fact that is reflected by the industry dummies (not reported).[14] Finally, the unexplained productivity (MFP) is significantly lower for all manufacturing firms in the recession period 1989-92 than in the periods that preceded and followed it (1985-88 and 1993-95).

To examine the sensitivity of scale parameters to the inclusion of the firm-size dummies, we estimated Equation (2) without the dummies. The results are reported in column (III). The regression results imply that the inclusion of firm-size dummies does not significantly affect the returns-to-scale parameter.

TABLE 3

REGRESSION RESULTS OF EQUATION (2)[a]

COEFFICIENTS	(I)	(II)	(III)	(IV)
Constant	2.2827*	2.4112*	2.4064*	2.2599*
	(32.9)	(36.2)	(39.3)	(31.6)
Dummy: 1989-92	-0.1748*	-0.1875*	-0.1761*	-0.1585*
	(-5.7)	(-6.0)	(-5.7)	(-4.9)
Dummy: 1993-95	0.0217	0.0140	0.0201	0.0235
	(0.6)	(0.4)	(0.6)	(0.6)
Dummy: Canadian-controlled	-0.1331*	-0.1345*	-0.1335*	-0.1053*
	(-4.2)	(-4.2)	(-4.2)	(-3.2)
Dummy: Canadian-controlled and in 1989-92	0.0437	0.0463	0.0432	0.0287
	(1.2)	(1.2)	(1.1)	(0.7)
Dummy: Canadian-controlled and in 1993-95	-0.0060	-0.0037	0.0028	-0.0096
	(-0.1)	(-0.1)	(0.1)	(-0.2)
Labour Quality	0.1677*	0.2029*	0.1652*	0.2086*
	(5.0)	(6.2)	(4.9)	(6.0)
Firm Age	0.0060	0.0088	0.0052	0.0054
	(0.7)	(1.0)	(0.6)	(0.6)
Unionization	-0.0447*	-0.0503*	-0.0377*	-0.0447*
	(-2.6)	(-3.0)	(-2.2)	(-2.5)
Exporting	-0.0034	0.0346**	0.0014	-0.0001
	(-0.2)	(1.9)	(0.1)	(-0.0)
Medium Size	0.1089*	0.1186*		0.1222*
	(3.7)	(4.0)		(4.1)
Large Size	0.1405*	0.1562*		0.1706*
	(3.6)	(3.9)		(4.2)

TABLE 3 (CONT'D)

COEFFICIENTS	(I)	(II)	(III)	(IV)
Labour Input	0.3810*	0.3932*	0.4032*	0.3786*
	(26.9)	(29.2)	(32.9)	(25.9)
Capital Input	0.1170*	0.0976*	0.1172*	0.1161*
	(13.2)	(12.0)	(13.2)	(12.8)
Intermediate Inputs	0.4903*	0.4962*	0.4854*	0.4832*
	(54.4)	(54.8)	(54.2)	(50.2)
Constant Returns to Scale	Not rejected	Not rejected	Not rejected	Rejected [b]
R^2 Adjusted	0.98	0.98	0.98	0.98
Observations	1,810	1,810	1,810	1,672

Notes: a If applicable, the estimates of the coefficients associated with industry dummies are not reported. The t-ratio is in parenthesis.
b Decreasing returns to scale.
(I): Full specification of Equation (2).
(II): (I) without industry dummies.
(III): (I) without firm-size dummies.
* Significant at the 5 percent level.
** Significant at the 10 percent level.

TABLE 4

PRODUCTIVITY OF CANADIAN-CONTROLLED RELATIVE TO FOREIGN-CONTROLLED FIRMS, MANUFACTURING SECTOR

	1985-88	1989-92	1993-95
RELATIVE PRODUCTIVITY LEVEL OF CANADIAN-CONTROLLED FIRMS[a] (FOREIGN-CONTROLLED FIRMS = 1)			
	0.75	0.85	0.82
Adjusted for all of the Following Factors:	0.73	0.82	0.78
Labour Quality	0.73	0.82	0.78
Vintage	0.75	0.86	0.82
Unionization	0.74	0.85	0.81
Exporting	0.75	0.85	0.82
Firm Size	0.75	0.85	0.82
MFP GAP BETWEEN CANADIAN-CONTROLLED AND FOREIGN-CONTROLLED FIRMS (LOGARITHM)			
MFP Gap	-0.2896	-0.1587	-0.2012
Total Contribution by all the Following Factors	0.0305	0.0416	0.0481
Labour Quality	0.0281	0.0366	0.0457
Vintage	-0.0037	-0.0030	-0.0022
Unionization	0.0061	0.0075	0.0052
Exporting	0.0001	0.0001	0.0000
Firm Size	-0.0002	0.0004	-0.0006
Unexplained MFP Gap	-0.3201	-0.2003	-0.2493

Note: a The relative productivity level of Canadian-controlled manufacturing firms is the exponential value of the logarithmic MFP gap between Canadian-controlled and foreign-controlled firms. The reported numbers are $\exp(\ln MFPG) = \overline{MFP}^{CAN}/\overline{MFP}^{FOR} = \overline{MFP}^{CAN}$, assuming that the MFP level of the foreign-controlled group is one.

In column (IV), we report the regression results after the observations related to the transportation equipment industry are removed from the sample. The regression results are very similar to those of column (I) in all respects.[15] The exclusion of the transportation equipment sector from the sample does reduce somewhat the coefficient of the ownership dummy, but the coefficient remains negative, large, and statistically significant.

The parameter estimates of Equation (2) in Table 3 are used to compute the MFP level gap between Canadian- and foreign-controlled firms. These results are reported in Table 4 as ratios of the productivity level of Canadian-controlled firms to that of foreign-controlled firms. A number less than one means that, on average, the productivity level of Canadian-controlled manufacturing firms is below that of foreign-controlled firms; if the ratio is greater than one, the relationship is reversed. Our estimates indicate that, on average, the MFP level of Canadian-controlled firms was 25 percent below that of foreign-controlled firms during the 1985-88 period, but this gap narrowed by 9 percentage points during the 1989-95 period.

To examine the sources of the productivity gap between the two sets of firms, we calculated the contribution of the difference between them with respect to each explanatory variable. These results are also presented in Table 4. Our calculations suggest that Canadian-controlled manufacturing firms, on average, have a slight advantage in labour quality vis-à-vis their foreign-controlled competitors. There are, however, no significant differences with respect to the other explanatory variables. Thus we conclude that the differences in the measured explanatory variables do not contribute significantly to the productivity gap between the two groups of firms.

Contribution of Differences in the Industrial Structure to the Productivity Gap

HOW MUCH OF THE AGGREGATE PRODUCTIVITY GAP between the two groups of firms is due to differences in their industrial structure? Are Canadian-controlled firms more concentrated in low-productivity industries than their foreign counterparts?

The industrial structure of the two groups of manufacturing firms — as determined by the distribution of gross output — is depicted in Table 5. It shows that a relatively high percentage of the activities of Canadian-controlled firms is in resource-based industries, such as lumber and wood, paper and allied products, and primary metals. In contrast, foreign-controlled firms specialize heavily in the transportation equipment industry, which accounts for more than 58 percent of the gross output of that group. In fact, all of the activity in the motor vehicle industry is controlled by foreign affiliates.

The relative MFP (level) of Canadian-controlled firms in individual manufacturing industries is reported in Table 6. In general, Canadian-controlled firms tend to be more productive than foreign-controlled firms in lumber and wood; paper and allied products; and electrical machinery. However, the reverse is true in stone, clay, and glass; transportation equipment; and other manufacturing.[16] In the remainder of the industries, both sets of firms are more or less productive.

TABLE 5

SAMPLE GROSS-OUTPUT SHARES OF MANUFACTURING INDUSTRIES BY FIRM GROUP[a]

	INDUSTRY GROSS OUTPUT AS A % OF MANUFACTURING GROSS OUTPUT					
	CANADIAN-CONTROLLED			FOREIGN-CONTROLLED		
INDUSTRY	1985-88	1989-92	1993-95	1985-88	1989-92	1993-95
Food and Allied Products	10.3	8.9	7.7	12.4	10.3	7.0
Textile Mill Products	1.5	1.4	1.6	0.0	0.1	0.2
Lumber and Wood	7.4	5.5	7.1	1.6	1.9	2.4
Paper and Allied Products	17.2	16.2	11.8	4.3	3.3	5.2
Chemicals	7.1	5.3	6.1	3.0	5.3	3.3
Stone, Clay, and Glass	0.3	0.3	0.0	1.4	1.8	2.8
Primary Metal	36.8	32.5	29.1	0.2	0.5	0.3
Electrical Machinery	10.8	12.8	18.5	3.2	3.1	2.6
Transportation Equipment	2.5	7.0	9.3	57.9	63.8	67.2
Other Manufacturing	6.2	10.1	8.8	16.0	10.0	9.0

Note: a Tobacco; furniture and fixtures; printing, publishing and allied; and leather industries are excluded because data were unavailable for at least one control group. Other industries not listed are included in other manufacturing.

TABLE 6

MFP OF CANADIAN-CONTROLLED INDUSTRIES RELATIVE TO THEIR FOREIGN-CONTROLLED COUNTERPARTS, MANUFACTURING SECTOR

INDUSTRY	1985-88	1989-92	1993-95
Food and Allied Products	1.01	1.08	0.98
Textile Mill Products	0.91	0.84	1.01
Lumber and Wood	1.02	1.14	1.17
Paper and Allied	1.00	1.04	1.03
Chemicals	0.95	0.96	0.89
Stone, Clay, and Glass	0.74	0.88	0.78
Primary Metal	0.97	0.88	0.90
Electrical Machinery	1.17	1.14	1.08
Transportation Equipment	0.58	0.70	0.65
Other Manufacturing	0.74	1.04	0.75
Total Manufacturing	0.75	0.85	0.82

It is interesting to note that the activities of Canadian-controlled firms are concentrated more in industries where they have a higher level of productivity than that or foreign-controlled firms, or one that is comparable.

To compute the impact of the differences in industrial structure on the MFP gap between the two groups of firms, we used the following equation:

$$(6) \quad \ln MFPG = \sum_{j=1}^{N^C} w_j^C \ln MFP_j^C - \sum_{j=1}^{N^F} w_j^F \ln MFP_j^F$$
$$= \sum_{j=1}^{S} \left[\overline{\ln MFP}_j^C \sum_{k=1}^{M_j^C} w_k^C - \overline{\ln MFP}_j^F \sum_{k=1}^{M_j^F} w_k^F \right]$$
$$= \sum_{j=1}^{S} (v_j^C - v_j^F)\, \overline{\ln MFP}_j^C + \sum_{j=1}^{S} v_j^F \ln MFPG_j \,,$$

where

N^i = the number of observations for control group i;
M_j^i = the number of observations for control group i in industry j;
S = the number of industries;
$\ln MFP_j^i$ = the logarithmic MFP level of firm j controlled by group i;
$\overline{\ln MFP}_j^i$ = the weighted sum of firm logarithmic MFP levels for control group i in industry j;

$\overline{\ln MFPG}_j^i$ = the logarithmic MFP gap between the two control group in industry j, $\ln MFPG_j = \overline{\ln MFP}_j^C - \overline{\ln MFP}_j^F$;

w_j^i = the gross-output share of observation j controlled by group i, where $\sum_{j=1}^{N^C} w_j^C = 1$ and $\sum_{j=1}^{N^F} w_j^F = 1$; and

v_j^i = the gross-output share of industry j in the industry controlled by group i, where $\sum_{k=1}^{M_j^C} w_k^C = v_j^C$, $\sum_{k=1}^{M_j^F} w_k^F = v_j^F$, and $\sum_{j=1}^{S} v_j^C = \sum_{j=1}^{S} v_j^F = 1$.

Thus, the MFP gap between the two sets of firms in any sub-period t (i.e. ignoring the subscript t) can be decomposed into two components — the contribution of the differences in industrial structure, and a residual that cannot be explained by the industrial structure. If there is no MFP gap at the industry level, then the total MFP gap between Canadian- and foreign-controlled firms is solely due to structural differences between the two groups. The opposite is true if the industrial structure is identical in the two groups. As we discussed earlier, however, the industrial structure of Canadian-controlled firms in the manufacturing sector differs considerably from that of foreign-controlled firms. A positive number for the first term of Equation (6) would mean that the industrial structure of Canadian-controlled firms is more conducive to productivity than that of their foreign-controlled counterparts and vice versa.

The results for the impact of the industrial structure on the MFP gap are presented in Table 7. The contribution of the industrial structure to the productivity gap is positive, implying that Canadian-controlled enterprises are, on average, more concentrated in high-productivity industries. Consequently, the MFP gap is entirely due to the relatively poor productivity performance of Canadian-controlled manufacturing firms. Therefore, our results contradict the popular perception that Canadian-controlled firms are concentrated in low-productivity industries.

TABLE 7

IMPACT OF THE INDUSTRIAL STRUCTURE OF CANADIAN-CONTROLLED MANUFACTURING FIRMS ON THEIR MFP PERFORMANCE

PRODUCTIVITY	1985-88	1989-92	1993-95
MFP	0.75	0.85	0.82
MFP Adjusted for Industrial Structure	0.70	0.81	0.73
Impact of Industrial Structure on MFP	+	+	+

CONCLUSION

THE MAIN PURPOSE OF THIS PAPER was to analyse the productivity performance of Canadian- and foreign-controlled manufacturing firms in Canada. Our estimates indicate that, on average, the multi-factor productivity level of Canadian-controlled firms was about 19 percent below that of foreign-controlled firms during the 1985-95 period. Testing for differences in firm vintage, labour quality, unionization, export orientation, and firm size revealed that these factors did not contribute to the productivity gap. The same applies to differences in industrial structure. In fact, the structure of Canadian-controlled firms places them in a relatively favourable position from a productivity performance point of view.

What factors, then, could account for the large productivity gap observed between the two groups? Several other studies suggest that managerial practices and strategies, and technological know-how might come into play. Martin (1999) shows that, in terms of company operations and strategy, Canada ranks sixth among the G-7 countries, just ahead of Italy. According to the Global Competitiveness Report (1998), Canada is also significantly falling behind its major competitor, the United States, in both technology and management. In addition, "[Canadian firms] are not as good as U.S. firms at developing and marketing new products" (Trefler, 1999). These results, in turn, suggest that the superior management practices and strategies, and technological know-how of foreign-controlled firms may have been largely responsible for the productivity gap between the two sets of firms.

In short, our research findings strongly suggest that a greater orientation towards foreign investment was not responsible for the poor productivity performance of the Canadian manufacturing sector in the 1990s. On the contrary, the Canada-U.S. productivity gap would have been larger, had that orientation not increased. A policy implication of our results is that Canada needs to rethink foreign ownership restrictions in several sectors where such restrictions are currently applied.

ENDNOTES

1 GRV use the cost of fuel and electricity per production employee as a proxy for capital intensity.

2 GRV use the following definitions:
Labour intensity = (wages and salaries)/(manufacturing value-added minus wages and salaries);
Energy intensity = (cost of heat and power)/(wages and salaries) or (cost of heat and power)/(cost of production materials);
Labour quality = (salaried workers/total employment) or (non-production workers) /(total employment);
R&D intensity = (R&D expenditures in industry)/(total shipments in industry).

3 Note, however, that many of these variables are not included in the above mentioned studies.

4 GRV only use micro-data in 1986. BD and CW base their analysis on industry-level data.

5 R&D is excluded here because it is biased against foreign affiliates as a result of the "headquarters" effect.

6 New technology is often embodied in new capital, and new capital is more productive than old capital; this is generally referred to as the "vintage effect" (see Wolff, 1996).

7 The introduction of firm-size dummies has no effect on the returns-to-scale parameter. As a matter fact, our estimation results indicate that the firms' production is characterized by constant returns to scale.

8 A Cobb-Douglas production function is used because it enables us to clearly define MFP as the ratio of output to a weighted sum of capital, labour, and intermediate inputs. Because of its simplicity, this functional form has been commonly used in productivity analysis; see, for example, Bernard and Jones (1996), Ehrlich et al. (1994), Griliches (1986), and Wolff (1991). Moreover, an MFP gap derived from a translog production function also takes a Cobb-Douglas form, as in Equation (2); see Jorgenson (1995).

9 We divide our sample period into three sub-periods (1985-88, 1989-92, and 1993-95) to capture productivity changes over time. Note that Canada was in recession during 1989-92.

10 All financial data are in Canadian dollars.

11 A firm is ultimately foreign-controlled if a majority of its voting rights are either held by foreign citizens or are held by one or more Canadian companies that are themselves foreign-controlled. Foreign ownership here is measured in discrete terms: Canadian-controlled or foreign-controlled. The data do not allow us to measure this variable in a more continuous fashion.

12 Three caveats are associated with the data. First, the average number of observations per firm in our sample is three. This may raise some difficulty in attempting to correct for potential autocorrelation. However, given that the sample is very unbalanced, autocorrelation is unlikely to be a big issue. Second, cross-ownership among some firms in our database causes them to be counted twice. However, this overlap problem is expected to have a minimal effect on our results since these

firms represent a small share of our data sample. Another issue emerges from the fact that some firms entered the market by acquisition or merger, whereas others were entirely new. We have tried to eliminate this problem by tracing a company's merger or acquisition record and using the earliest year of incorporation of firms involved in mergers or acquisitions. Although this process is by no means exhaustive, we expect the problem caused by acquisitions and mergers to be minor.

13 The reported results assume homoskedasticity. Different specifications of heteroskedasticity were considered, but the results they generated were not significantly different and have not been reported here.

14 check the sensitivity of parameter estimates, we estimated Equation (2) without industry dummies and reported those results in column (II). They indicate that the influence of the labour-quality and export-orientation variables is correlated with industry-specific impacts. The influence of labour quality is much stronger than before, implying that certain industries tend to have more employees with above-average education and skills. The coefficient of the export-orientation variable has the expected positive sign and is significant at the 10 percent confidence level, in sharp contrast to the estimation results obtained with industry dummies. It is interesting to note also that the exclusion of industry dummies does not significantly change the magnitude of the coefficient on the ownership dummy. The first implication of that observation is that industry structure is not responsible for the productivity difference between Canadian-controlled firms and their foreign-controlled counterparts.

15 The largest productivity gap is observed in the transportation equipment industry. The regression is designed to determine if any other industries contribute to the productivity gap between Canadian- and foreign-controlled firms in the manufacturing sector.

16 On the surface, it is surprising that Canadian-controlled firms lag so far behind their foreign-controlled counterparts in the transportation equipment industry, given the close integration of the North American motor vehicles and parts sector. Two reasons explain this phenomenon. First, foreign-controlled firms dominate the industry, especially its motor vehicles component. Second, the production of the industry is very heterogeneous, with foreign-controlled firms specializing in motor vehicles, while Canadian-controlled firms are concentrating in other transportation equipment (such as aircraft).

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APPENDIX

DESCRIPTION OF DATA SOURCES

TABLE A1

LIST OF VARIABLES AND PARAMETERS

VARIABLES	DESCRIPTION	SOURCES
S	Net Sales (Current $)	Compustat/Compact Disclosure
I	Inventory Change (Current $)	Compustat/Compact Disclosure
YN	Gross Output (Current $)	$= S - I$
KN	Net PPE (Property, Plant and Equipment, in Current $)	Compustat/Compact Disclosure
MN	Cost of Goods Sold, Net of Total Labour Compensation (Current $)	Compustat/Compact Disclosure
L	Total Number of Employees	Compustat/Compact Disclosure[1]
PY	Gross Output Deflator 19 industries)	Statistics Canada
PK	Capital Deflator (19 industries)	Statistics Canada
PM	Intermediate Goods Deflator (19 industries)	Statistics Canada's KLEMS Database
Y	Gross Output (Real $)	= YN/PY
K	Capital Stock (Real $)	= KN/PK
M	Intermediate Inputs (Real $)	= MN/PM
Q	Employment Share of White-collar Workers	Compact Disclosure; Micromedia's *Profile Canada*
V	Year of Incorporation	Compact Disclosure; Micromedia's *Profile Canada*; Moody's International
U	Unionization	Compact Disclosure; Micromedia's *Profile Canada*;
E	Exporting Dummy	Compact Disclosure; Micromedia's *Profile Canada*; Canadian Trade Index of Alliance of Manufacturers and Exporters Canada
D	Ownership Dummy	Compact Disclosure; Micromedia's *Profile Canada*; *Inter-Corporate Ownership*

TABLE A1 (CONT'D)

VARIABLES	DESCRIPTION	SOURCES
P_1	Period Dummy for 1985-88	
P_2	Period Dummy for 1989-92	
P_3	Period Dummy for 1993-95	
S_1	Size Dummy for Firms with Capital of Less Than $30 Million	
S_2	Size Dummy for Firms with Capital Greater than $30 Million but Less than $150 Million	
S_3	Size Dummy for Firms with Capital Greater than $150 Million	

Note: [1] Net PPE (property, plant and equipment) is used because it takes depreciation into account, thus allowing for technological obsolescence; gross PPE does not depreciate old capital and thus tends to exaggerate the capital stock of firms.

Part V
Productivity in the New Economy

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18

Productivity in the New Economy: Review of Recent Literature

SUMMARY

EVIDENCE FROM THE UNITED STATES indicates that productivity growth within the *new economy* — defined as computing, software development, communications, information processing, e-commerce and related activities (hereafter referred to as the IT sector) — has grown at a rapid pace in recent years. Whether measured in terms of labour productivity (LP) or multi-factor productivity (MFP), productivity growth in the IT sector has clearly outpaced that of the remainder of the U.S. economy.

Productivity improvements in the IT sector have been driven by two fundamental cost trends: The rapid decline of computing costs and the increasing capacity and falling incremental costs of telecommunications. These cost trends are related to technological improvements in computers and communications that, as yet, show no sign of abating.[1]

As a result of these developments, the IT sector has grown much more rapidly than the rest of the U.S. economy. Furthermore, the growth of output and productivity in this sector has been strong enough to have a significant impact on aggregate output and aggregate labour productivity growth.

But although the proliferation of computing and telecommunications technology throughout the U.S. economy has proceeded at a rapid pace, there is some disagreement about the impact of the IT sector on the rest of the economy and, in particular, on productivity growth.

Whether the recent spurt in economic growth in the United States will continue — hence raising the *speed limit* for U.S. potential growth — or whether it is largely a *flash in the pan* is a key issue that forecasters and macroeconomic policy analysts have to resolve.

An important issue facing Canadian policy makers and analysts is whether it can be anticipated that the recent spurt in U.S. growth will be replicated in

some fashion in Canada. Will Canada's potential growth rate increase, and will that increase be sustained over the medium term?

The expansion of the IT sector may have important structural and transitional effects on labour markets. As the long expansionary period continued in the United States — with real growth in the latest years higher than in the earlier recovery period — the unemployment rate has declined to about 4 percent without signs (until very recently) of an acceleration of inflation. The equilibrium unemployment rate, or NAIRU (non-accelerating inflation rate of unemployment), in the United States may have declined by as much as 2 percentage points.[2]

By reducing transaction costs in product markets and search costs in labour markets, the growth of the IT sector should tend to reduce the NAIRU. On the other hand, the rapid expansion of the IT sector could generate structural imbalances (shortages of IT workers coupled with layoffs elsewhere) that may raise the NAIRU during the transition period. (The U.S. economy may have avoided the latter effect because of strong growth in aggregate demand — the proverbial tide that raises all boats.) Again, these developments have relevance for Canada. Reduced transaction and job search costs should lower the NAIRU (although the adverse transitional effects may be more apparent here if demand growth is more moderate).

The remainder of this chapter is arranged as follows. In the next section, we examine some methodological issues and briefly review the U.S. literature. We focus mainly on academic work, but we also draw on other sources for key facts. In the third section, we review two studies by Steven Globerman and one by Ronald Hirshhorn, Serge Nadeau and Someshwar Rao. In the fourth section, we consider the implications of the U.S. analysis for Canada. In the fifth and final section, we summarize the policy implications of this analysis.

MEASURING THE IMPACT OF THE NEW ECONOMY: METHODOLOGICAL ISSUES

THE DEVELOPMENT OF THE IT SECTOR IN THE UNITED STATES has had important effects on aggregate demand and aggregate supply. The large investments in computers, software and telecommunications infrastructure have added substantially to aggregate demand. One of the strongest components of final demand in the United States (and Canada) in recent years has been investment in machinery and equipment (M&E) which, in the United States, includes most software and hardware. Investment in IT equipment and software account for about 80 percent of M&E spending growth since 1995.

Such a surge in investment contributes to the growth of output when the economy has sufficient slack to expand. But it is important to note that these demand effects cannot have a permanent impact on growth: once capacity limits are reached, increased strength in one component of aggregate demand must be offset by slower growth in other components if a rise in inflation is to be avoided.

Nevertheless, the impact of the IT sector expansion on aggregate demand is an important factor in the explanation of the rapid growth experienced in the United States over the past five years.

There are other demand effects associated with the development of the IT sector as demand is displaced from other sectors towards IT products: Telecommunications — e-mail, faxes, etc. — may displace ordinary mail, and e-commerce may displace mail order and traditional retail sales. The measurement of e-commerce and its effects on the economy have become a major issue.[3] We have some concerns about the methods used to measure the size of the Internet economy in studies of this type, but these do not seriously impact upon the points made in the present review. For a recent official estimate of the size of e-commerce, see "E-Commerce and Business Use of the Internet" (*The Daily*, Statistics Canada, August 10, 2000).

While these developments are important, as they reflect and reinforce the reallocation of resources towards the IT sector, they do not indicate how IT contributes to aggregate economic growth over the medium term (although investments associated with the development of e-commerce add to aggregate demand, as mentioned above). The contribution of the IT sector to long-term growth requires an analysis of its supply side effects. Does it raise the level and growth of labour productivity? Of multifactor productivity? It is here that, in many ways, the most serious impact of the new economy on long-run growth and productivity will take place.[4] The next section considers these issues for the U.S. economy.

The Contribution of the New Economy to Productivity Growth in the United States

The role of the IT sector in explaining the acceleration of U.S. economic and productivity growth was the focus of a recent panel discussion organized by the Brookings Institution (Jorgenson and Stiroh, 2000a; and comments by Gordon, 2000b, and Sichel, 2000).

There is consensus on two important issues. First, productivity growth within the IT sector was a significant contributor to the rate of MFP growth and to the acceleration of MFP growth after 1995. Second, rapid price declines for IT goods and software have led to an increase in investment, which stimulated aggregate labour productivity growth.

But opinions differ on two important issues: the extent to which the adoption of IT products has stimulated MFP outside the IT sector, and whether the estimated increase in real economic growth in recent years is sustainable or transitory.

Jorgenson and Stiroh (2000a,b) argue that MFP growth outside the IT sector is highly sensitive to the rate of deflation of IT prices. Gordon (2000a,b) estimates that cyclical factors account for about one-half of a percentage point of growth over the past four years, and that MFP growth outside the IT sector was relatively low and did not accelerate. In contrast, Jorgenson and Stiroh (2000a,b) and Oliner and Sichel (2000) estimate that MFP outside the IT sector increased by 0.4 percent. It would appear that the differences between Gordon's estimate and the other two estimates are largely due to the cyclical adjustment term used by Gordon.

However, it is interesting to note that these authors do not attribute widespread spillovers from IT production to MFP growth outside the IT sector. Rather, the contribution of IT products takes place through capital deepening in non-IT sectors, augmenting labour productivity but not MFP.

Jorgenson and Stiroh point out that there is considerable uncertainty in projecting productivity growth related to data quality and to the short period of observation of accelerated growth: "Caution is warranted until productivity patterns have been observed for a longer period.... We must emphasize that the uncertainty surrounding intermediate-term projections has become much greater as a consequence of widening gaps in our knowledge..." (2000a, p. 185).

So far, we have focussed on quite aggregate measures of productivity: the U.S. economy divided into two broad sectors, IT and everything else. Two recent studies have examined productivity performance at a more detailed level.

In a study published in this volume, Sharpe and Gharani (2002) review U.S. productivity growth at the industry and sector levels. They find that, on average, labour productivity in the broad service sector increased more rapidly than productivity in the goods sector during the most recent 5-year period (1995-99). They put forward two explanations for this service sector productivity *renaissance*: improved measurement of service output and the large investments in IT made by service sector firms and organizations.

In a series of papers, Nordhaus (2001a,b,c) considers productivity measurement issues at the industry and sector levels. He finds that the new economy sectors account for 0.65 percentage points of the 1.82 percent increase in productivity growth in the U.S. business sector over the 1996-98 period. (Note that this estimate lies within the range of estimates of the three studies mentioned above.)

Within manufacturing, he finds that virtually all of the acceleration in productivity growth is accounted for by two industries: Electrical Machinery and other Electrical Equipment, and Industrial Machinery and Equipment. But when the direct effects of the new economy sectors are removed from the more aggregate data, a substantial acceleration of labour productivity growth remains. He concludes that "the productivity rebound is not narrowly focussed in a few new economy sectors" (2001b, p. 21).

Whether the recent acceleration of productivity growth outside the new economy sectors is attributable to investment in and utilization of IT equipment and technology cannot be determined from the data analyzed by Sharpe and Gharani and by Nordhaus. Their results show that labour productivity growth accelerated in these sectors. But without data on capital stocks, we cannot determine whether multi-factor productivity also accelerated.[5]

Furthermore, except for the capital deepening effects of investment in computer and communications equipment and related software, any residual acceleration of productivity growth outside the IT sector could be related to cyclical and structural factors.

We summarize what we have learned from our brief review of the U.S. literature as follows:

- The development of the IT sector itself directly contributed to an acceleration of aggregate MFP growth in the U.S. economy.
- The high rate of investment in IT software and hardware contributed to an acceleration of labour productivity outside the IT sector.
- The combination of those two factors has increased U.S. potential growth by 0.6 to 1.0 percent, thus raising the *speed limit* guideline for monetary policy.
- The NAIRU in the United States has declined, partly as a result of the transitory effects of higher productivity growth, and partly as a result of more efficient labour and product markets.

We shall consider below the implications of this analysis for Canada in the section entitled *Will Canada Share in the Productivity Surge? Implications of the U.S. Analysis*.

REVIEW OF COMMISSIONED STUDIES

IN THIS CHAPTER, WE ALSO PRESENT A REVIEW of three studies commissioned by Industry Canada.

ELECTRONIC COMMERCE AND PRODUCTIVITY GROWTH: DEFINING AND ASSESSING THE LINKAGES, BY STEVEN GLOBERMAN

IN HIS STUDY, GLOBERMAN SETS OUT VERY WELL THESE LINKAGES, and we agree with his observation that, in spite of the vast and diffuse literature on e-commerce, surprisingly little has been done on its possible impacts on productivity.[6] We also agree with him, however, that this sector is so new and expanding so rapidly, and the data is so thin, that little in the way of concrete conclusions can yet be drawn.

The study amply rewards a complete reading. Our review summarizes those parts of the study that we have found to be most interesting and new, and we add occasional questions or commentaries when appropriate.

Globerman's study has four major sections. The first offers some definitions for electronic commerce (hereafter *e-commerce*) and for types of productivity or efficiency gains. The second lays out a schema of the various paths by which e-commerce could potentially affect productivity. The third section looks for evidence that these linkages are occurring and how large they might be. The fourth section examines some policy implications.

In the definitions section, the author sensibly confines e-commerce to "commercial transactions conducted on the Internet or the World Wide Web". These transactions are, as usual, further divided into *business-to-consumers* (B2C) and *business-to-business* (B2B). The author notes that there is a wide range of estimates of the size of e-commerce from a number of sources, but that almost under any measures the extent of e-commerce is small relative to total retail and wholesale trade. (He further notes that there is wider agreement that B2B makes up the lion's share at some 70 to 80 percent of total e-commerce.)[7] At this point, the author makes the comment that with e-commerce being relatively so small, its potential impact on productivity at the aggregate level must be limited, and will remain so until e-commerce gets significantly larger. We have found this to be a common misconception: that the primary impact of e-commerce on aggregate productivity will come from productivity gains *within* the sector itself, and that the size of the productivity contribution depends on the size of the sector. We do not believe this to be the case, and indeed the rest of Globerman's study also makes this quite clear: the primary impact of e-commerce on aggregate productivity will occur through its impact on other sectors. For this to happen, the e-commerce sector need not be large, nor indeed does it need to show huge productivity gains itself.

In much of the remainder of his definitions section, the author discusses traditional classifications of efficiency, primarily using the customary breakdown into allocative, technical and dynamic efficiency. In fact, he makes relatively little use of these categories in the rest of his discussion, concentrating instead on, in our opinion, a more interesting breakdown into cost and competitiveness effects. However, whenever a categorization is used, the author does a great service in pointing out that the potential productivity impacts of e-commerce come from a wide set of linkages. He concludes this section with the excellent observation that the fundamental contribution of e-commerce is in improved communications, which will make their impact felt through two main channels: reduced transaction costs, and increased competitiveness and contestability.[8]

In the section where he considers the linkages between e-commerce and productivity, the author discusses in greater detail the impacts on transaction costs and competitiveness. Within transaction costs, he distinguishes four subcategories: search, contracting, monitoring, and adaptation costs. For the latter three, the author sees relatively little scope for cost-reduction from e-commerce until principles of standardized contracts are worked out. However, e-commerce has the potential to reduce search costs significantly. This is especially true for *search goods* — those goods whose different characteristics can be readily distinguished by consumers. Computers and some financial products fall within this category and have made their way into e-commerce quite rapidly. *Experience* goods, where the typical buyer requires some contact with the product (a test drive for a car, pinching a tomato), may or may not be amenable to e-commerce depending on the particular experience required and the skill of website designers. (Some goods can indeed be *experienced* over the Internet, e.g. music or game demos.) The kinds of goods least likely to make it into e-commerce are *credence* goods — those where some trust or faith in the quality of the good or service must be built (e.g. medical care). Here, branding can help and existing firms may carry that advantage into e-commerce if they choose to take this route. There is no question, however, that the improved communication system offered by e-commerce can dramatically lower search costs, both B2C and B2B, for some kinds of goods and services.

On the issue of competition and contestability, the author notes that "the predominant view of e-commerce is that it will promote increased competition." The primary mechanism for this is, again, the reduction of search costs, which would presumably increase the geographic size of a market, bringing in more competitors. Supposedly, e-commerce also lowers barriers to entry into a market because it is relatively inexpensive to set up an e-commerce site. However, the author points out some important limitations to these effects: For many goods, the ability of potential buyers to search a wider area may not be matched by a willingness of sellers to increase their distribution channels or deal across administrative borders. While the cost of setting up an e-commerce site may be low, for any physical product the need to inventory, warehouse and ship is not eliminated and can still represent a barrier to entry. Finally, the proliferation of web sites and the difficulty new sites may have in obtaining customer notice and trust may still be a formidable obstacle to entry. Bundling strategies and purchasing networks may also serve to limit the competitive pressures of e-commerce on more established sales networks. In brief, while the author believes that there will certainly be some pressures for additional competition through e-commerce, he is much more sceptical of the potential impact of e-commerce on productivity through improved competition than through reduced transaction costs.

In the third major section of his study, Globerman makes a very interesting assessment of the micro-economic studies indicating whether the linkages between e-commerce and productivity discussed above are actually occurring. (Some, of course, may still occur in the future.) Before considering the evidence, he lists eight hypotheses about what should be observable if these linkages were actually at work; for example: "reductions in search costs should lead to less market segmentation and increased price uniformity across geographic markets associated with e-commerce," or "e-commerce transactions should have lower costs as a consequence of the reduction of ... intermediation activities." After listing these hypotheses, he proceeds to test them against the micro evidence under two main groupings: *Pricing* and *Costs*.

On the whole, the evidence Globerman could find for pricing effects is quite thin. There are clear cases of lower prices for particular items purchased via e-commerce (e.g. on-line brokerage services), but many others where there are none (e.g. air fares), and some where prices seem to be higher but purchases are still made because additional services or convenience are offered through e-commerce. While there are, of course, exceptions, little evidence has been found of a breakdown in borders or of a wide extension of a market's geographic reach, especially across national boundaries. Without this increased competition, downward pressure on prices has not been as forthcoming as predicted. Price changes appear to be more frequent in e-commerce, but price dispersion seems to be as large as in traditional sales media.

However, there does appear to be strong evidence that e-commerce reduces costs. Globerman sorts costs into three categories: costs of executing a sale, costs of procuring inputs, and costs of making and delivering products. The evidence he reviews suggests significant savings in all three categories. Where they can be used, websites are cheaper to maintain per dollar of sales than *storefronts*, and the Internet offers major savings in terms of customer support and after-sale service. For purchased inputs, estimates show savings in the range of 2-40 percent, with significant examples at the higher end of the range. Some of these savings may be due to pooled market power derived from coordinated purchasing, but most represent true efficiency gains. Finally, there are large cost savings in distribution where services (like financial transactions) can occur directly over the Internet, but also sizeable savings from reduced inventories and administration costs when goods are being sold. An OECD estimate puts cost savings at around 14 percent at the wholesale level, and at 25 percent at the retail level.

Briefly, then, Globerman finds strong evidence of cost savings, at least compared to the impact on prices. But he notes that the implication of this result for productivity growth over time depends on whether these cost savings are one-time (more likely in our view) or ongoing, and on the relative growth rates of sectors more and less amenable to cost savings from e-commerce. The author concludes by citing an OECD study where it has been estimated that e-commerce will reduce economy-wide costs by about one-half to two-thirds of a percentage point — and that these savings are a proxy for total factor productivity (TFP) gains. He indicates that this estimate is likely to be conservative because it does not include welfare gains accruing to consumers from greater choice — but the latter will not show up in productivity as currently measured anyway, although it is a gain nonetheless.[9]

Globerman's final section deals with policy issues, which he divides into three major areas. First, because a number of benefits come from efficiencies associated with the expansion of geographical markets, improved international agreements are needed to foster e-commerce. The author notes that in the area of international relations, Canada's restrictions on foreign ownership in, for example, banking and telecommunications may be limiting Canadian participation in the full international benefits of market integration and technology and innovation transfer. The second policy area mentioned is competition policy. Here, the challenge is in cooperative arrangements and joint ventures among e-commerce participants that might end up restricting competition and reducing the potential benefits of greater competition promised by e-commerce. The third area is that of "agglomeration policies and domestic industrial policies." In this case, Globerman is concerned about whether e-commerce will shift economic activity among regions in Canada, either further concentrating it or dispersing it. He calls for careful study to check for such impacts.

Finally, in his overall policy conclusions, he expresses the opinion that there is little in the way of an "economic case for emphasizing the promotion of e-commerce" in public policy, and especially through subsidies or tax advantages. He believes it would be difficult to show that such programs would have benefits offsetting the associated *dead-weight* costs and, moreover, that they would distort the evolutionary transition from conventional forms of commerce to e-commerce that would undoubtedly impose costs on the former. We heartily agree on this point, but we note that the study is not primarily written to support this particular conclusion.

Globerman's review is, in our opinion, an excellent starting point for assessing the linkages between e-commerce and productivity growth. In particular, three major conclusions stemming from the study need to be followed up:

1. To overstate somewhat, "not all of the hype about e-commerce is true." For example, while some cost reductions are indeed found to be large and significant, both theory and evidence to date suggest a much weaker impact than commonly touted in terms of price reductions, increased competition and greater geographical reach.
2. The productivity impacts of e-commerce may occur largely outside the sector itself. This is a point that we will emphasize elsewhere: Some of the largest productivity gains from e-commerce will not occur necessarily within e-commerce itself or as e-commerce replaces traditional retail sales, but in other sectors as e-commerce comes to be used in place of more traditional retailing and wholesaling. This will show up in actual measured productivity increases in other sectors as B2B e-commerce permits administrative, inventory and labour savings, and in improved consumer welfare from greater choice via B2C e-commerce (although the latter will not affect aggregate productivity as currently measured).
3. In the policy realm, e-commerce will benefit from breaking down international barriers and enhanced competition, and from the better education and infrastructure provision that will assist all productivity growth, but there is no need for special subsidies or tax breaks.

INNOVATION IN A KNOWLEDGE-BASED ECONOMY: THE ROLE OF GOVERNMENT BY RONALD HIRSHHORN, SERGE NADEAU AND SOMESHWAR RAO

THE SECOND STUDY EXAMINED HERE PROVIDES a timely and effective summary of its subject and well repays a full reading. We present our brief review and comments in what follows.

The study proceeds in three broad sections. In the first, the authors make the point that technological change is important for growth and competitiveness and that Canada has some major deficiencies. In the second, they review the various market failures that may produce less-than-optimal investment in R&D and in science and technology. In the third section, they examine how governments can offset some of these failures.

The authors do not spend much time making the case that technological improvement is important — nor need they do so. Most of this section is used to outline Canadian deficiencies, especially in comparison with the United States.

These are evidenced by relatively low R&D expenditures in Canada, a low number of patents, and the relatively slow pace of technology adoption in Canadian manufacturing. They also point to relatively lower levels of Canadian machinery and equipment investment in the 1990s as an indication of the fact that Canada is falling behind. Our own view is that, while one can quibble about some of these numbers (e.g. M&E investment is measured differently in Canada than in the United States, where it includes software, which will bias the comparison), the basic conclusion is still valid and it is worthwhile for Canada and Canadian governments to be concerned, so long as the comparisons do not lead to panic and result in wasteful and misguided public policy.

As the authors point out, the principal reason for private market failure in R&D and technology is the large spillovers from such activities that will not accrue back to originating firms. This is likely to lead to serious underinvestment. The problem may be less serious for a small economy like Canada, which will benefit from worldwide spillovers, but it is made worse for a small country to the extent that such investments are risky and *lumpy*; large firms can pool risks and undertake large projects (where there are economies of scale), which will potentially disadvantage a smaller country. Imperfect information, or the costs of acquiring information, can be a serious impediment to small and medium size firms (SMEs), especially in what is already a small country. The problems underlined by the authors are real, but a healthy note of caution pervades their discussion: Newer research has made some of the arguments for intervention less clear than before, and there is a wider appreciation that governments cannot *omnipotently* address cases of market failure as imperfect information hampers governments as well.

It is in discussing the present and potential role of governments in Canada's technology sector that the study makes its largest contribution. Again, and importantly, there is a healthy tone of scepticism and humility. At the same time, the authors make the plea that government policy not be assessed against impossibly perfect ideals, but rather on the humbler criteria of whether it makes a net improvement or meets a cost-benefit test. On this basis, they find that a number of Canadian programs have been success stories, as has been recognized by the OECD, while it is also clear that there have been some failures.

They consider three major areas for policy action: 1) promoting R&D; 2) facilitating national innovation; and 3) creating a favourable framework for technological advances.

Under *promotion of R&D*, it seems safe to say that the authors think (and we agree) that Canada is doing about all it can and should in terms of providing tax incentives and subsidies — which are among the most generous available. Additional funds and resources would be better invested elsewhere — for example, in general corporate tax reductions that would also have a favourable impact on risk/return calculations for R&D and for the location of high-tech activity in Canada. On the international dimension, they strongly make the point that, as a small country that generally benefits from spillovers, it is in Canada's interest to work toward fewer restrictions on technology transfers and, where appropriate, to make sure that intellectual property (IP) rights do not become overly restrictive.

As for *facilitating innovation*, the authors see a strong role for government in disseminating information and in bringing research groups together. A catalogue of some government programs deemed to be successful in this area is provided, with a prominent place for the Network of Centres of Excellence Program. But again, the authors are (rightly) cautious: "Part of the appeal of existing programs is that government is mainly acting as a facilitator or catalyst and public expenditures are relatively modest. With large program expenditures, there is a danger that marginal benefits will be less than those that could alternatively be achieved by reducing tax rates." (p. 31)

Finally, the authors consider how the wider policy framework could encourage technology and productivity growth. Our own view is that this dimension of technology policy is extremely important, and it is very encouraging to see it receive such strong emphasis in an Industry Canada study.

Hirshhorn, Nadeau and Rao highlight a number of policy framework initiatives. The first rests on the fact that Canada is a small economy that depends strongly on technology transfers from abroad. The authors conclude that policy should generally continue to seek greater openness to trade, and especially foreign direct investment (FDI). They point to general taxation levels as possibly important tools for attracting or keeping human talent and FDI, with all the associated technology gains. While we are not convinced by the *brain drain* arguments for across-the-board personal income tax cuts, this aspect merits further examination, and should be very interesting as the recent federal and provincial personal income tax cuts take effect.

The authors are also concerned about the relatively low level of M&E investment in Canada compared to the United States. They point to the high federal debt burden as a possible cause. While this factor might have contributed to higher real long-term rates in Canada in the past, tight monetary policy, stagnant growth in the early and mid-1990s, and weak profit performance would be just as important in our view. In any event, the federal deficit has been replaced by a surplus, M&E investment is now climbing strongly, and the focus must be on the future. In our view, Hirshhorn, Nadeau and Rao are right to suggest further debt reduction to stimulate M&E investment, but from hereon the motive should not be to reduce the risk premium on Canadian borrowing but to get the proper mix of fiscal and monetary policies. We make this point elsewhere but, briefly put, as the Canadian economy approaches full employment, it is imperative to determine how much of its limited resources will go into investment and how much will go into current consumption and government spending. With too many personal tax cuts and government spending increases, there is a risk that the economy will overheat, that monetary policy will tighten and that the dollar will rise. This would impede investment and possibly competitiveness and FDI, with eventual losses in technological improvement and productivity gains. On the other hand, tighter fiscal policy (and, consequently, more debt reduction) will widen the scope for lower interest rates and a lower dollar, which would encourage investment and, possibly, FDI. It is a difficult choice between *jam today* and *jam tomorrow*, but we can probably say that Hirshhorn, Nadeau and Rao are right in arguing that there is a major risk of too much *jam today* in the way aggregate fiscal policy is presently conducted.

As part of their framework review, the authors indicate that there is still a strong role for human capital development and support to education at all levels. They note that Canada already devotes a relatively high level of resources to this area, but that significant improvements could be made on particular aspects and, perhaps, in making current expenditures more efficient.

Hirshhorn, Nadeau and Rao reiterate the importance of having a competitive corporate tax system (instead of more generous direct R&D support) and strongly endorse (as do we) the proposals of the Technical Committee on Business Taxation to make the overall corporate tax system more neutral.

Finally, the authors point to the need to remove policies that impede economic change and transformation. They note, with our approval, that government policies are shifting away from bail-outs and more toward assisting workers and families respond to change. They would like to see further efforts to free-up markets and break down barriers within the Canadian economy.

Briefly, the study by Hirshhorn, Nadeau and Rao provides an excellent review of the policy challenges of the new economy and technological change in general, with refreshing caution about what Canadian governments can do and a willingness to consider the wider policy context and its implications.

THE LOCATION OF HIGHER VALUE-ADDED ACTIVITIES BY STEVEN GLOBERMAN

THE THIRD STUDY, *The Location of Higher Value-added Activities*, by Steven Globerman, discusses a very particular issue linked to the information economy and its policy challenges — namely, whether and why some high-tech industries cluster together and what the implications of this phenomenon might be for policy. As this is, again, a very specific subject not immediately related to the issues on which our review focuses, we will provide only a brief summary.

Globerman concludes that there is a growing perception, at least among economists, that knowledge-intensive sectors exhibit regional clustering for a variety of reasons. Presumably, if policy makers wish to foster knowledge-intensive sectors in Canada they need to ask why such clustering occurs and if policy can help the process — especially in the context of a small economy, since clustering may favour larger economies. The author finds that the essential policy objective is to promote "conditions within regions that contribute to the realization of scale economies" since these are the main reason why clustering occurs. As he notes, "relevant conditions include an educated workforce ... infrastructure, and workable competition." He also suggests that it is probably better, especially for a small country, to build on existing locations with specialized advantages rather than attempting to compete directly with rival locations.

Globerman also points to a danger, in the Canadian context, that provincial governments will try to compete with each other to attract clusters, wasting resources, and possibly ending up with several nascent centres that will not reach the required *take-off* size. The federal government will need to mediate amongst regional claims and avoid the temptation to foster multiple clusters to achieve shorter-term political ends. In the meantime, as the author states, "competition policy, laws and regulations surrounding foreign investment, immigration law, federal tax legislation, and funding for R&D" are available to promote clustering, without selecting where it will necessarily occur. It should be noted that here, as in the other two studies reviewed, the emphasis is on general, broadly-applied policies, rather than on the selection of *winners*, either by firm, sector, technology or regional concentration.

Will Canada Share in the Productivity Surge? Implications of the U.S. Analysis

As mentioned above, the recent acceleration of productivity growth in the United States has probably raised U.S. potential growth by 0.6 to 1.0 percent. Whether this higher potential growth can be sustained over the medium term is an open question. Also open is the question of whether, and how much, Canada can expect to share in the productivity surge that has apparently begun in the United States.

This issue is put in clearer light in Figures 1 and 2. The first depicts real GDP growth in the Canadian and U.S. economies since 1993 (the value for 2000 is a forecast produced in the second half of 2000). As can be seen from Figure 1, growth has not been all that higher in the United States than in Canada over these eight years, although 1996 and 1998 stand out as years when U.S. growth clearly outpaced Canadian growth.[10] However, much of the growth that Canada achieved in the second half of the 1990s came from putting more individuals to work, while in the United States the unemployment rate remained relatively low and steady during that period, and growth was achieved through increased labour productivity (as measured by GDP per employee).

The clear break in productivity performance between the two countries is immediately apparent in Figure 2. Again, the obvious question raised by that chart is whether the productivity growth surge will carry over to Canada.

In our role as Canadian economic forecasters for the Policy and Economic Analysis Program at the University of Toronto, we naturally had to wrestle with this question. In this section, we summarize our very tentative (and somewhat cautious) analysis and projections thus far.

FIGURE 1

REAL GDP GROWTH, UNITED STATES AND CANADA

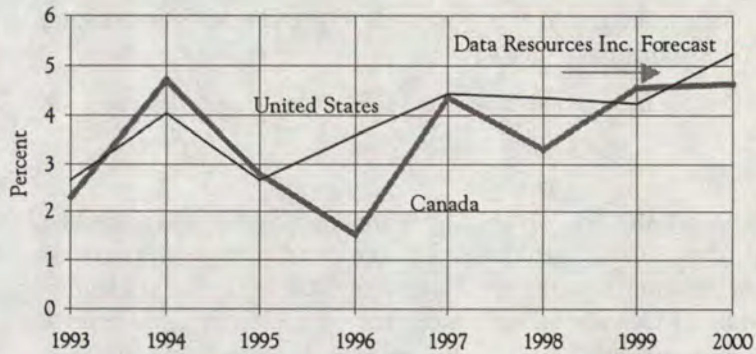
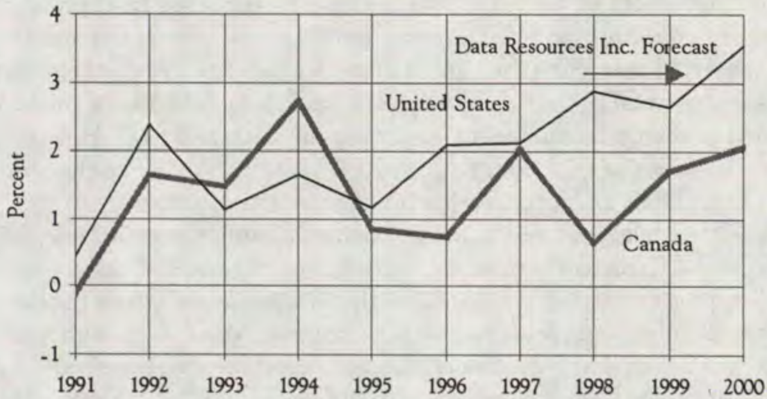


FIGURE 2

PRODUCTIVITY GROWTH: GDP/EMPLOYEE, UNITED STATES AND CANADA



With the increased labour productivity growth in Canada in 2000:Q2 and 2000:Q3, some observers have argued that we should enjoy a comparable period of robust growth as the benefits of investment in IT products and higher productivity growth in IT production are realized. While we share some of this optimism, at least based on our 2-year and 3-year forecasts, and project some productivity improvements, we nevertheless conclude that it would be inappropriate to predict that Canada will achieve the same increase in growth over the next four years as the United States recorded over the past four years. Our caution rests on three types of factors, which can be summarized as follows:

1. Data, including different measurements and possible mismeasurement problems;
2. Unique factors on the supply side in the United States, including the U.S. industrial structure; and
3. Unique factors on the demand side in the United States.

Data Issues

FOR SEVERAL YEARS, the United States and Canada have measured real GDP differently. Specifically, in the United States, statistical agencies have estimated the real or inflation-adjusted components of GDP using Fisher-chain price indexes, while in Canada a Paasche current-weight deflator has been used. In addition, software purchases are counted as equipment investments in the United States, while in Canada software is treated as a business expense. Canada has planned to switch to the U.S. method in the May 2001 National Accounts release, but until revised data are published, comparisons between the two countries and forecasts based on the older accounting method are difficult to interpret. The problem is especially acute because it is primarily in the IT areas that the differences between the two deflation methods are most pronounced, and where counting (or not) software purchases as investment matters the most. It seemed that when the United States adopted the Fisher-chain method, past estimates of GDP were revised upward (and since estimates of employment remained unchanged, estimates of output per employee also rose). However, preliminary estimates of Canadian GDP in 2000 based on the Fisher-chain method show a lower GDP, and especially lower investment in equipment.

Until the release of new Canadian data, we cannot more accurately compare U.S. and Canadian productivity growth over the last five years, or provide Canadian projections that are more directly comparable with those published for the United States (and with recent U.S. history). Meanwhile, with the older method (and even with preliminary estimates from the newer method), there is little evidence that Canada is beginning to see productivity growth comparable to that achieved by the United States in recent years, although a somewhat smaller increase may have emerged in 2000.

We should also mention at this point that we have some reservations about the way in which quality improvements are treated in calculating the real output of the IT sector, which in turn leads to massively falling price estimates and, therefore, estimates of large increases in real output and real output per employee in this sector. It appears that every progress made in processor speed or increase in hard drive capacity or bandwidth is being treated as of equal value with past advances, whereas they may be of diminishing marginal utility to consumers and diminishing marginal value to business purchasers (which true hedonic estimates try to reflect). In any event, this problem clearly goes beyond the scope of our study, but it could well be a source of distortion in productivity measurements and international comparisons.

UNIQUE SUPPLY-SIDE FACTORS IN THE UNITED STATES: THE SIZE OF THE U.S. IT SECTOR

IT IS IMPORTANT TO UNDERSTAND that the productivity surge in the United States has so far been unique to that country. There is little evidence yet that Canada has begun to experience it, or any corresponding evidence from other mature industrialized countries. Again, part of the explanation may be linked to measurement, but some clearly has to do with the fact that the U.S. economy has a larger IT sector.[11] As a result, the direct contribution of IT to potential growth in Canada will be smaller than in the United States. It is noteworthy that the computer manufacturing industry, which accounts for the bulk of multifactor productivity (MFP) growth within the IT sector in the United States, is much smaller in Canada, so the direct contribution of MFP growth in the IT sector will be correspondingly lower.

Implications of Three Recent U.S. Studies

Three recent studies have attempted to identify the various contributions to the productivity growth surge in the United States. Making use of these studies and of estimates of the relative size of the IT sector in Canada (roughly one-quarter of the relative size of this sector in the United States), we have attempted to draw some conclusions about how large a productivity gain might be expected in Canada if it gets the same proportional increase in productivity from the IT sector. These calculations are summarized in Tables 1 and 2.

Table 1 shows comparable breakdowns of the sources of the surge in labour productivity growth observed over the second half of the 1990s in studies by Jorgenson and Stiroh (2000a,b), Oliner and Sichel (2000), and Gordon (2000a,b).

TABLE 1

LABOUR PRODUCTIVITY CHANGES, UNITED STATES (PERCENTAGE POINTS)

	JORGENSON AND STIROH	OLINER AND SICHEL	GORDON
ESTIMATES FOR THE RECENT U.S. EXPERIENCE	1995-98 VS 1990-95	1995-99 VS 1990-95	1995-99 VS 1972-95
Estimated Change in Labour Productivity Growth Rate Relative to Previous Period	1.0	1.0	1.4
Less: Cyclical or *Transitory* Impact	0.0	0.0	0.7
= Estimated Change in Trend Productivity Growth	1.0	1.0	0.7
Contributions to Change in Trend Productivity Growth:			
Capital Deepening	0.5	0.5	0.3
of which: IT Sector	0.3	0.5	0.1
Other Sectors	0.2	0.0	0.2
Labour Composition	-0.1	-0.1	0.1
Multifactor Productivity	0.6	0.7	0.3
of which: IT Production	0.2	0.3	0.3
Other Sectors	0.4	0.4	0.0
Total for IT Factors	0.5	0.8	0.4

Source: *Brookings Papers on Economic Activity1*, 2000, paper by Jorgenson and Stiroh, and comments by Sichel and by Gordon.

Note that the comparison periods vary slightly with each study, and that Gordon is comparing the later 1990s to a much longer previous period.

Each study divides the increased productivity into three sources: changes in labour composition (a small item in all cases), capital deepening, and increases in MFP. Gordon adds a fourth source: a cyclical or transitory component that occurs as the economy reaches, or perhaps exceeds, full employment and firms increase hours of work and overtime and make shop-floor or organizational adjustments under the pressure of an extremely tight labour market (tighter, in fact, than at any time since the 1960s). In Gordon's estimates, this component accounts for half of the improvement recorded between 1972-95 and 1995-99.

Capital deepening refers to the fact that labour will become more productive if it has more capital to work with, even for a given level of technology. All three authors estimate a significant impact from capital deepening linked to the investment surge that began in the United States in the early 1990s. Each author also divides the impact of capital deepening between that occurring within the IT sector itself and that occurring in all other sectors. The estimates vary widely: In Gordon's longer comparison time-frame, about two-thirds of the impact of capital deepening occur outside the IT sector, while Oliner and Sichel

TABLE 2

LABOUR PRODUCTIVITY CHANGES, CANADA (PERCENTAGE POINTS)

	JORGENSON AND STIROH	OLINER AND SICHEL	GORDON
(FIGURES BASED ON U.S. ESTIMATES)	1995-98 VS 1990-95	1995-99 VS 1990-95	1995-99 VS 1972-95
Estimated Change in Labour Productivity Growth	1.0	1.0	1.4
Less: Cyclical or *Transitory* Impact	0.0	0.0	0.7
= Estimated Change in Trend Productivity Growth	1.0	1.0	0.7
Total for IT Factors	0.5	0.8	0.4
Less: 75% of IT Factors for Smaller IT in Canada	-0.4	-0.6	-0.3
Less: Contribution of Software to Growth (not counted in Canada)	-0.1	-0.1	-0.1
Total Adjustment for Canada	-0.5	-0.7	-0.4
Canadian Trend if It Follows U.S. Trend (with adjustments)	0.5	0.3	0.3
Add Back Cyclical or *Transitory* Impact (assuming Canada does not go above NAIRU)	0	0	0.5
Canadian Trend if It Follows U.S. Trend (plus *transitory* impact)	0.5	0.3	0.8
Reference or Base Canadian Productivity Growth Rate	1.3 (1990-95)	1.3 (1990-95)	1.1 (1974-95)
Possible Canadian Productivity Growth Rate if It Follows U.S. Trend	1.8	1.6	1.9

see all of the impact of capital deepening occurring within the IT sector, with nothing left for the other sectors. Finally, Jorgenson and Stiroh show that 60 percent of the capital deepening effect occurs within the IT sector.

Multifactor productivity is, of course, the component of growth unaccounted for by labour and capital, and it is usually taken to represent technological or organizational change in its broadest form. Again, the authors divide the contribution of MFP between that occurring in the IT sector and that occurring in all other sectors. Here also, the results differ rather widely: Gordon sees all of his MFP estimate of 0.3 percent per year as occurring in the IT sector, but he also allows for a separate economy-wide cyclical or transitory component that may be picking up organizational change in non-IT sectors. Oliner and Sichel (2000) and Jorgenson and Stiroh (2000a,b) each estimate a larger MFP contribution and see a more even split between the IT sector and non-IT sectors, with the larger share in each case going to the non-IT sectors.

The bottom line of Table 1 adds together the IT specific components of each estimate. These range from a high of 0.8 percent per year (out of a total of 1.0 percent per year) in Oliner and Sichel to a low of 0.4 percent per year (out of a total of 1.4 percent per year) in Gordon. Jorgenson and Stiroh find that roughly one half of the 1.0 percent productivity surge in the second half of the 1990s is specific to the IT sector.

Table 2 shows, for each study, what would be the effect on Canadian labour productivity if Canada were to follow the U.S. experience, but with allowance for the smaller size of the IT sector in Canada. The first four lines of Table 2 simply repeat the estimated changes in trend labour productivity growth from Table 1, and the sum for IT-specific factors calculated at the bottom of that table.

We next subtract 75 percent of these IT-sector effects to allow for the fact that IT manufacturing is approximately one-quarter as large in the Canadian economy as it is in the U.S. economy.[12] We also subtract an estimate of the U.S. contribution to growth from software purchases (although, as noted earlier, this item will need to be added back when revised Canadian accounts come into use).

We then subtract the total adjustments for Canada from the initial trend productivity growth estimates of the three studies. Thus, for Jorgenson and Stiroh, the estimated change of 1.0 percent must have 0.5 percent subtracted from it to account for the smaller IT sector and for the contribution from software, leaving a possible addition of 0.5 percent to Canadian trend productivity growth if the other items identified by Jorgenson and Stiroh also occurred in Canada. For Oliner and Sichel and for Gordon, the implied additional productivity growth for Canada is 0.3 percent in each case. For Gordon, however, it is also fair to add some cyclical or transitory effect, which could well occur as Canada approaches full employment. Rather arbitrarily, we have added 0.5 percent for this effect — less than the 0.7 percent Gordon estimates for the United States because it is less likely that Canada will get as close to, or beyond, full employment as a 4.0 percent unemployment rate implies for the United States.

The possible impact on future productivity growth in Canada (if it follows the U.S. pattern) ranges from a low of 0.3 percent for Oliner and Sichel (because so much of their estimate is centered on the IT sector) to 0.5 percent for Jorgenson and Stiroh, and to 0.8 percent for Gordon (primarily because the *transitory* component is large). The reference or base average labour productivity growth rates to which these additions would be applied are given in the second-last line of Table 2, where the time span is equivalent to the comparison period used in each of the U.S. studies. Over 1990-95, labour productivity growth averaged 1.3 percent in Canada (it averaged approximately the same over 1995-2000). With the additions estimated from Jorgenson and Stiroh and for Oliner and Sichel, the productivity growth rate could be expected to rise to 1.6 percent through 1.8 percent if we follow the U.S. surge pattern. If the Gordon estimate is used, the reference or base productivity growth rate is somewhat smaller at 1.1 percent, but as the Gordon addition is larger, a productivity growth rate of 1.9 percent is obtained.

TABLE 3

RECENT MEDIUM-TERM FORECASTS: UNITED STATES AND CANADA

UNITED STATES		
Congressional Budget Office (from Jorgenson and Stiroh, 2000a,b)		
GDP Growth, 1999-2010	2.80%	(actual)
	3.10%	(potential)
Labour Productivity (GDP/hour)	1.90%	
CANADA		
University of Toronto (PEAP* – November 2000)		
GDP Growth, 1999-2010	3.10%	
Labour Productivity (GDP/employee)	1.80%	

Note: * Institute for Policy Analysis, Policy and Economic Analysis Program.

Recent Forecasts

A recent Congressional Budget Office (CBO) forecast of output and labour productivity growth in the United States is presented in Table 3. Jorgenson and Stiroh (2000a,b) cite this forecast, which places potential growth for the U.S. economy at 3.1 percent annually over the next eleven years (1999-2010), with actual performance somewhat weaker at 2.8 percent, which allows for some below-potential growth to raise the unemployment rate slightly and forestall inflationary pressures. Jorgenson and Stiroh argue that, based on their decomposition of the sources of productivity improvement in the second half of the 1990s, this forecast is reasonable and achievable.

Table 3 also shows our own projection for GDP growth and labour productivity growth in Canada over 1999-2010, based on our longer-term forecast of November 2000. As can be seen, labour productivity growth is estimated to average 1.8 percent over the period — at the median of the estimates derived from the three U.S. studies. Note that if Canada were to achieve this average productivity growth between 1999 and 2010, it would surpass the productivity performance of each of the three previous decades.

UNIQUE DEMAND-SIDE FACTORS IN THE UNITED STATES

ON THE DEMAND SIDE, investments in IT have contributed to the strength of aggregate demand in the United States. Strong demand growth has accompanied the supply-side improvements in productivity, allowing the U.S. economy not only to realize its higher potential growth, but also to grow above that potential and reduce the unemployment rate to 4 percent.

Whether Canada could anticipate such higher aggregate demand growth is problematical. Unlike the U.S. economy, where domestic demand dominates foreign trade, and the economy itself is an engine of global growth, the Canadian economy is trade-dependent (and the global impact of Canada's aggregate demand growth is modest).

Also, the current degree of slack in the Canadian economy may not provide as much room for non-inflationary growth above potential as existed in the United States in 1995. This situation depends on the value of the non-accelerating inflation rate of unemployment (NAIRU) in Canada (and the Bank of Canada's estimate of this rate). A related issue of importance is whether the recent increase in the labour force participation rate is continuing. If *discouraged* workers can be drawn back into the work force, above-potential growth becomes more feasible.

Because of the greater importance of foreign trade to Canada, real demand growth here depends more strongly on the growth of our trading partners, particularly the United States. Given the likelihood that U.S. growth will slow down, at least to the U.S. potential rate, that development will dampen Canada's export growth.

With core inflation creeping up towards the mid-point of the Bank of Canada's target zone, we would anticipate that the Bank will validate any productivity improvement on the supply side, but would be unlikely to accept growth much above the increased potential rate.

On balance, therefore, we project that Canada's growth rate over the next ten years will be slightly above potential, averaging 3.1 percent per year.

POLICY IMPLICATIONS

THIS FINAL SECTION CONSIDERS the policy implications of the analysis. We first consider macro-economic policy issues, and then turn to review some selected micro-policy issues.

MACRO-ECONOMIC POLICY ISSUES

THE MACRO-ECONOMIC EFFECTS OF IT include increased productivity growth and increased potential output growth, possibly accompanied by a decline in the NAIRU. These effects have important implications for the appropriate conduct of monetary (and fiscal) policies. With a higher *speed limit* allowed by higher potential growth, demand management policies should seek to accommodate higher real demand growth. Easier monetary policies coupled with selective fiscal policies can be used to stimulate demand growth while facilitating increased investment, which will reinforce potential growth.

To determine whether the NAIRU has declined, the Bank of Canada should tolerate growth somewhat above potential, allowing the unemployment rate to probe the limit of the NAIRU.

MICRO-ECONOMIC POLICY ISSUES

MICRO-ECONOMIC POLICY ISSUES have been ably considered in the three background studies. We fully concur with the view that governments should not attempt to pick winners. We do not need a new industrial policy designed to favour IT. The growth of the new economy deserves policy support where possible, but so does high-productivity growth in general, without any attempt to select winners, whether by sector, type of technology, region or cluster.

Rather, the government should focus on policies that facilitate private sector adaptation. These include appropriate investments in public sector infrastructure (like supporting networks that generate positive externalities), training and education, and designing a tax structure that does not penalize new economy industries. The 5-year corporate tax reduction plan contained in the 2000 federal budget addresses some of these issues. We would recommend timely implementation of the planned corporate income tax cuts (which would reduce the tax burden on services relative to manufacturing). Other tax reforms should be considered to improve the overall tax structure while reducing barriers to entry in the IT sector. Examples include increased capital cost allowance (CCA) rates for systems software and computers, and longer carry-forward periods for ordinary business losses.

Nevertheless, it is inevitable that advocates and participants of that sector should plead for special treatment. For example, a number of special tax measures were advocated in *Fast Forward*, a report prepared by the Boston Consulting Group (2000) for the Canadian E-Business Opportunities Roundtable. Tax and other disincentives are also the subject of another report released by the Roundtable on September 18, 2001 (including, apparently, a proposal arguing that loan rates are too high for e-business students).

Fast Forward identifies several tax issues that may act to inhibit both the creation of start-up companies and efforts to take them public. These include the higher rate of tax on capital gains in Canada relative to the United States, the absence of rollover provisions for venture capitalists, and the tax treatment of stock options. However, the federal budget of February 2000 has taken three important steps to address these concerns:

1. The general rate of tax on capital gains was lowered by about 4 percentage points.

2. The tax treatment of stock options was changed to make options much more attractive. Henceforth, stock options are taxable only at the time the stock is sold.

3. A rollover provision will allow some venture capital investments to be realized and reinvested without attracting capital gains tax.

Moreover, the 5-year tax reduction plan commits the federal government to eliminating the 5 percent surtax for higher income taxpayers and to reducing the basic federal tax rate on the middle-income bracket by 3 percentage points.

In some provinces, tax changes will also contribute to a more favourable tax environment. In Alberta, a flat tax (at a rate of 10.5 percent) will go into effect at the beginning of next year. Next year, therefore, the top marginal rate of tax on capital gains will be 27 percent in that province. Ontario is phasing-in another round of general tax reductions. When it switches to a tax on income base system, we anticipate that the existing high surtax rate in that province (currently at 56 percent) will be reduced, allowing top marginal rates on capital gains to decline from their current 32 percent level.

Other features of the Canadian tax system are actually favourable to start-up firms. Canada's tax treatment of small Canadian-controlled private corporations (CCPCs) is more favourable than that offered in the United States. CCPCs are taxed at low rates (varying from 18 percent to 22 percent depending on the province) on the first $200,000 of active business income. This allows retained earnings to be reinvested in business assets at a low rate of taxation. Equally important, qualifying shares in CCPCs (which include large and small firms) are eligible for the $500,000 lifetime capital gains exemption.

While the 2000 federal budget represents a good start, more has to be accomplished. A further reduction in capital gains tax rates would be feasible as part of a more general reform of the tax treatment of corporate income, dividends and capital gains. The current tax credit for labour-sponsored venture funds could be replaced by a more general venture capital incentive regime.[13]

However, any such incentive should be generally available to *all* qualifying ventures, and not restricted to Internet or new economy ventures. We see no need for special tax incentives aimed at e-businesses, as recommended in *Fast Forward*.[14] A tax incentive restricted to Internet-related activities would have distortion effects and could lead to abuse.

ENDNOTES

1 Indeed they have accelerated in recent years; see Jorgenson and Stiroh (2000a,b).

2 The United States has also benefited from a number of favourable transitory factors: a strong dollar and, until 1999, stable energy prices.

3 One large and important study in Canada is *Fast Forward: Accelerating Canada's Leadership in the Internet Economy*, produced by the Boston Consulting Group for the Canadian E-Business Opportunities Roundtable. It borrows some of its methods and principles from various studies, collectively entitled *Internet Economy Indicators*, completed by researchers from the University of Texas at Austin.

4 This point is also made in some of the studies commissioned for Industry Canada's Conference on Productivity that are reviewed in the third section.

5 Jorgenson and Stiroh (2000a,b) analyze industry data on total factor productivity over the 1958-96 period, but these obviously cannot be used to assess the recent acceleration of productivity growth.

6 Most of the large-impact studies of e-commerce focus on contributions to GDP and employment — and most of these studies, as we argue elsewhere, are seriously flawed as they only count output (rarely even GDP) and employment in new e-commerce itself and make no allowances for displacement from more traditional enterprises.

7 More recent data on the size and distribution of the e-commerce sector are forthcoming from the special Statistics Canada survey conducted earlier in 2000.

8 The latter term refers to potential competitors who, through low barriers to entry into a market or service, will keep the market competitive by their potential to contest any attempt by current market participants to exert market power.

9 In his review, Globerman includes, on a number of occasions, consumer welfare gains as part of the productivity linkages from e-commerce. Again, these welfare gains are important, but they will not show up in productivity statistics as currently measured.

10 Data released after the Industry Canada Conference on Productivity, but before the final revisions made to this study, indicate that Canada's growth will likely exceed U.S. growth in 2000.

11 While on the subject of uniqueness, it is also worth recalling how unexpected the U.S. growth and productivity surge was. We examined a medium-term forecast we had prepared in July 1995 and compared the projection for average growth over 1995-2000 against actual data. As it turns out, our forecasts for Canadian output and productivity growth were slightly too high: we projected an average output growth rate of 3.8 percent over 1995-2000, while a growth rate of about 3.5 percent was actually achieved. The forecast for productivity growth was 1.7 percent per year, while a rate of 1.3 percent was achieved. However, our projection for the United States, borrowed from major U.S. forecasters, put the average growth rate at 2.6 percent over 1995-2000, while a rate of 4.0 percent was actually achieved, with an inflation rate more than one-half of a percentage point lower than predicted.

12 It might be argued that Canada's IT sector could grow faster than the IT sector in the United States given its smaller starting size, and could add more to Canadian growth than this one-quarter proportion. However, given the massive growth of IT manufacturing in the United States in recent years, even matching this growth rate in Canada will require some work, and the possibility that Canadian IT growth rates will exceed recent U.S. rates must remain an enticing possibility rather than a basis for forecasting.

13 See Jack M. Mintz and Thomas A. Wilson, "Capitalizing on Cuts to Capital Gains Taxes," C.D. Howe Institute Policy Commentary No. 137, February 2000, p. 21.

14 See "Create a Time-limited Tax Incentive" on p. 37 of *Fast Forward*, and "Permit Deferred Capital Gains Taxation on Qualified Investments" under "Internet-related Companies" on p. 39.

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Electronic Commerce and Productivity Growth: Defining and Assessing the Linkages

INTRODUCTION

> In general, it is thought that electronic commerce can significantly improve the efficiency of economies, enhance their competitiveness, improve the allocation of resources and increase long-term growth. (OECD, 2000, p. 55)

WHILE THERE IS SUBSTANTIAL DISAGREEMENT about how quickly and dramatically electronic commerce (henceforth, e-commerce) will affect real income levels, there is little doubt that the emergence and growth of e-commerce promises to have substantial beneficial effects on worldwide standards of living. Since e-commerce is still in its very early stages of adoption, it is arguably foolhardy to attempt to predict the impacts it will ultimately have on real income levels, let alone the timing of these impacts. Nevertheless, policymakers must come to grips with issues such as whether and how the adoption path of e-commerce should be stimulated by government policies. As well, forecasts of future real economic growth rates may need to be modified in light of the e-commerce phenomenon, especially if e-commerce results in major improvements in economic efficiency as some experts predict.

Notwithstanding the enormous literature on e-commerce that has accumulated in both academic and trade journals, to our knowledge no systematic attempts have been made to classify and assess, even on a very preliminary basis, the linkages between e-commerce and productivity levels and growth rates. Since productivity growth is ultimately the source of higher real standards of living in society, the linkages between e-commerce and productivity should be of particular interest to policymakers. In particular, a comprehensive identification of these potential linkages could help policymakers better formulate and implement policies that might leverage larger productivity benefits from private sector investments in e-commerce activities.

Hence, the broad purpose of this study is to identify and evaluate the potential linkages between e-commerce and the productivity performance of the Canadian economy. A related purpose is to identify important public policy issues conditioning the linkages identified, and, as a related consequence, identify topics for future research consideration.

The study consists of the following sections. In the section entitled *Defining the Concepts*, we set out some definitions of e-commerce and productivity, as well as some historical data on the two phenomena, by way of background. The section entitled *Linking E-Commerce to Productivity Growth* describes a conceptual framework within which the major linkages between e-commerce and productivity performance might be identified and evaluated. The section entitled *Assessing the Linkages* discusses some preliminary evidence bearing upon the nature and magnitude of the linkages identified in the preceding section. The last section, entitled *Policy Issues*, identifies and briefly discusses several prominent policy issues.

DEFINING THE CONCEPTS

IN THIS SECTION, definitions of e-commerce and productivity performance are provided. While precise definitions are not of particular importance, explicit definitions of the phenomena are useful in order to avoid unintended confusion. As well, available data are easier to interpret and evaluate if the reader understands the activities and economic outcomes to which they apply.

DEFINITION OF ELECTRONIC COMMERCE

> There is no universal definition of electronic commerce because the Internet marketplace and its participants are so numerous and their intricate relationships are evolving so rapidly.
> (NOIE, 1999, p. 2)

THE TERM *E-COMMERCE* DESCRIBES MANY USES of modern telecommunications and information technology. For example, an encompassing definition would include any form of business activity conducted on the electronic medium (Wigand, 1997).[1] This would include electronic data interchange (EDI), electronic mail and related types of communication. In fact, while EDI has been equated with e-commerce in the past, it is more appropriately viewed now as a subset of e-commerce. In the vernacular, EDI encompasses business-to-business (B-to-B) electronic transactions. Commercial transactions involving sales to households are identified as business-to-consumer (B-to-C) electronic transactions.

Non-commercial transactions conducted electronically do not qualify as e-commerce by most definitions, although, as a practical matter, the boundary between commercial and non-commercial transacting is somewhat vague.

For purposes of this report, commercial transactions must be carried-out over the Internet/World Wide Web (henceforth, Internet) to be characterized as a part of e-commerce. While many commercial transactions are carried out on private electronic networks, the main hypotheses linking e-commerce to economic growth focus on public access networks, of which the Internet is the dominant model.

THE MAGNITUDE AND NATURE OF ELECTRONIC COMMERCE

SYSTEMATICALLY COLLECTED DATA on the magnitude and nature of e-commerce transactions are generally unavailable. One set of estimates of global e-commerce activity is provided in Table 1. The wide range of estimates reported for 1999 underscores the tentative nature of the available evidence. More certain is the fact that B-to-B transactions comprise the largest share of e-commerce — indeed, as much as 70 percent to 80 percent of total e-commerce (Coppel, 2000).

Most observations and estimates available on the use of the Internet for commercial purposes apply primarily to the United States. Such data further highlight the embryonic nature of e-commerce. For example, it is estimated that, in the first quarter of 2000, online retail sales in the United States totalled US$5.26 billion. This represented just 0.7 percent of the total economy's US$747.8 billion in retail sales. While formal estimates of B-to-B e-commerce are unavailable, such sales are thought to be less than 1 percent of commercial transactions (Blackman, 2000).[2] An obvious inference that one might draw from these observations is that, at current utilization rates, e-commerce is a relatively modest economic phenomenon, and substantial productivity effects are unlikely in the absence of significant continued growth in its adoption.[3]

TABLE 1

CONSULTANTS' ESTIMATES OF WORLDWIDE E-COMMERCE (US$ BILLIONS)

CONSULTANTS	1999	2003	AVERAGE ANNUAL GROWTH
E-Markets	98.4	1,224	89
IDC	111.4	1,317	85
Active Media	95.0	1,324	93
Forrester (low)*	70.0	1,800	125
Forrester (high)*	170.0	3,200	108
Boston Consulting Group	1,000.0	4,600	46

Note: * Includes Internet-based EDI.
Source: Coppel (2000, p. 7).

To be sure, the consensus expectation is that e-commerce will continue to grow rapidly, both in absolute terms and in relation to overall economic activity. For example, one (perhaps extreme) forecast projects that B-to-C commerce will grow to US$108 billion by the end of 2003.[4] Rapid growth is also projected for B-to-B e-commerce. According to one estimate, that form of e-commerce will more than triple in volume by 2003 compared to its 1999 level (Hof, 1999).

It is less clear that the scope of e-commerce, especially the B-to-C variety, will expand over time. In this regard, data reported in Table 2 highlight the relatively narrow product scope of B-to-C e-commerce to date. In particular, online computer hardware and software sales have constituted a disproportionately large share of household products purchased on the Internet. Online purchasing in the areas of travel, entertainment, books and music has also been relatively robust.

There is some evidence of a recent broadening of product categories for B-to-C commerce. For example, there has been a relative increase in the magnitude of sales in previously laggard categories such as clothing, furniture and groceries (Table 3). This development is apparently due, in part, to more women shopping online.[5] Nevertheless, computers and software, books and music, and travel remain the dominant product categories for Internet retail activity.[6] Clearly, a broadening of the commercial transactions carried out on the Internet must occur if e-commerce is to have substantial economy-wide productivity consequences.

TABLE 2

ESTIMATES OF INTERNET SHOPPING
($ MILLIONS)

	1997	2000
PC Hardware and Software	863	2,901
Travel	654	4,741
Entertainment	298	1,921
Books and Music	156	761
Gifts, Flowers and Greetings	149	591
Apparel and Fashion	92	361
Food and Beverages	90	354
Jewelry	38	107
Sporting Goods	20	63
Consumer Electronics	19	93
Other	65	197
Total	2,444	12,090

Source: "The Virtual Mall Gets Real», *Business Week,*" January 26, 1998, p. 90-91.

TABLE 3

PERCENT OF ALL ONLINE STORES
OPENED FOR LESS THAN THE NUMBER OF YEARS SPECIFIED

	1 YEAR	2 YEARS	3 YEARS
Gifts, Jewellery, Flowers and Greetings	17.3	3.2	11.9
Hobbies, Crafts and Antiques	16.5	12.8	12.6
Medical, Legal and Other Services	12.2	5.6	6.0
Apparel and Accessories	11.5	5.6	11.9
Computer Products and Software	11.5	13.6	15.9
CDs, Tapes and Books	9.4	15.2	17.9
Toys and Games	6.5	1.6	4.0
Art	2.9	1.6	1.3
Banking, Finance and Investment	2.9	1.6	6.6

Source: "A Hard Sell Online? Guess Again," *Business Week*, July 12, 1999, p. 143.

PRODUCTIVITY

PRODUCTIVITY PERFORMANCE IS USUALLY IDENTIFIED by two concepts: productivity level and productivity growth. The productivity level is related to the standard of living in a country, while productivity growth is the major determinant of the rate of increase in living standards over time. In fact, for Canada, the two performance measures have been strongly related over the past four decades (Harris, 1999). Hence, it does not seem necessary to distinguish between the potential linkages between e-commerce and productivity levels, on the one hand, and e-commerce and productivity growth rates, on the other. For convenience, the focus of this report will be on the potential linkages between e-commerce and changes in productivity levels (i.e. productivity growth) over time.

The most meaningful measure of how efficiently a society is utilizing its productive resources is multi-factor productivity. Multi-factor productivity growth equals the growth rate of real output less a weighted sum of the growth rates of capital and labour inputs, where the weight of each factor corresponds to its share of the cost of producing the output. The aggregate rate of productivity growth will, therefore, reflect productivity growth rates of individual micro-economic units, as well as the reallocation of resources across micro-economic units enjoying different productivity performances. The latter is ordinarily related to changes in allocative efficiency, whereas the former is ordinarily related to changes in technical efficiency.

ALLOCATIVE, TECHNICAL AND DYNAMIC EFFICIENCY

WHILE IT IS DIFFICULT, as a practical matter, to distinguish precisely among the various sources of productivity improvement, conceptual distinctions can be made, and such distinctions are helpful.

Allocative Efficiency

A market is allocatively efficient if it is not possible to increase the value of real output by reallocating production from one producing unit to another, or by reallocating final output from one consumer to another. Under a set of conditions that define a perfectly competitive market, allocative efficiency will be maximized. At least two conditions are worth highlighting, as many observers argue that the emergence and growth of e-commerce will affect them. The first is the degree to which information about prices and other elements of potential transactions is available to market participants. To the extent that such information is costly or otherwise difficult for market participants to obtain, significant departures from allocative efficiency are more likely. The second is the extent of competition or contestability. The more imperfect the competitive process, the larger the likely gap between actual and potential allocative efficiency.[7] Conversely, reductions in information costs and increases in competitive pressures are likely to improve allocative efficiency.

There is a growing body of evidence that the productivity growth process is fundamentally driven by the reallocation of resources from low-productivity growth activities to high-productivity growth activities. In particular, productivity growth is observed as more-productive plants expand and less-productive plants contract (Harris, 1999). The impact of public policies on productivity growth will therefore depend in part on the way they influence the reallocation of resources among producing units. Likewise, a potentially important linkage between e-commerce and productivity growth is through the former's impact on the reallocation of resources from less-productive to more-productive users of inputs.

Technical Efficiency

Production units are technically efficient if they cannot produce their current level of output with fewer inputs, given existing knowledge about technology and the organization of production. Equivalently, a firm is producing efficiently if, given the quantity of inputs used, no more output could be produced based on existing knowledge (Perloff, 1999, p. 162). Conceptually, a similar interpretation can be applied to consumers. That is, individual consumers are technically efficient if they cannot achieve higher levels of utility without spending more money on goods and services.

In broad terms, a producer will be technically efficient if inputs are obtained at the lowest possible cost, and if they are used in combinations that maximize real output. Once again, improved information, in this case about the availability of cheaper inputs, or cheaper input combinations, could be an important source of improved efficiency. Similarly, a consumer will be technically efficient if final outputs are obtained at the lowest possible cost. So, improved information about the prices and other attributes of final goods and services could improve productivity. On the other hand, the linkage between competition and technical efficiency is less certain. While market power allows a firm to be technically inefficient, without necessarily being driven from the market, owners of firms would presumably want to maximize technical efficiency, since it is consistent with maximizing profitability. To be sure, a variety of so-called principal-agent problems might lead to non-profit-maximizing behaviour on the part of producers. In the event, the existence of market power enables producers to survive while failing to maximize profits. Therefore, as a practical matter, it is likely that increased competition will be associated with improved technical efficiency.

Dynamic Efficiency

In its broadest sense, dynamic efficiency encompasses changes in knowledge about technology and the organization of production such that producers are able to increase real output without commensurate increases in real inputs.[8] To the extent that resulting cost savings, or quality improvements, are passed through to final consumers, improved dynamic efficiency makes it possible for final consumers to realize higher standards of living at the same nominal income levels. Alternatively, to the extent that dynamic efficiency gains are passed backward to factors of production, final consumers will enjoy improved nominal incomes that will enable them to purchase more goods and services at existing prices.

Dynamic efficiency is often equated with technological change or innovation. In theory, changes in the organization of production may occur without technological change. For example, the scale and scope of a firm's production might change without the incorporation of new capital equipment or other alterations of the underlying techniques for producing and distributing output. In turn, changes in scale and scope might improve efficiency over time. As another example, by providing workers with training and further education, firms may be able to increase the value of output above the cost of the training and education provided.

As a practical matter, operating at a different scale or scope, or utilizing more highly trained workers, will usually require firms to adopt new or improved physical inputs and/or organizational techniques. That is, the broad concept of dynamic efficiency will largely overlap the theoretically more circumscribed concept of technological change. Again, for purposes of this paper, precise terminological distinctions are unnecessary. Observers highlight the organizational changes in production and distribution that are facilitated by e-commerce. Equivalently, observers highlight the linkage between e-commerce and technological change, and that is the linkage this report focuses on.

The potential linkages between e-commerce and dynamic efficiency are, at the same time, more diffuse and indirect than are the linkages between e-commerce and other components of efficiency. Perhaps the most important potential direct impact of e-commerce on dynamic efficiency is the capability that e-commerce provides both firms and households to reorganize the ways in which they carry out their economic activities.[9] While there are innumerable possibilities in this regard, an example often cited is the enhanced ability of producers to contract out the production of inputs that were formerly produced in-house. With improved control over the contracting-out process, cost savings and improved quality of inputs might be realized by producing units over time. Households can also use the Internet to contract-in services that might be difficult or excessively expensive to acquire through more conventional channels. An example is education. The proliferation of higher educational programs on the Internet offers a new way for individuals to invest in human capital. As a result, one might expect greater investment in human capital over time, with resulting long-run improvements in productivity.

Another example is the elimination of many forms of transactional intermediation made possible by e-commerce. In this context, information is exchanged directly between the supplier and the customer without the need for intervention by specialist intermediaries. In effect, transactional activities such as order taking and sales confirmation are reorganized so as to reduce or eliminate the utilization of more conventional inputs. Observers often highlight the example of the brokerage industry, where online trading companies carry out retail stock market transactions largely without the services of traditional customer representatives.

In many cases, reductions in transaction costs underlie the potential linkage between electronic commerce and dynamic efficiency. For example, by facilitating easier and cheaper identification of possible sub-contractors, search costs are mitigated as a barrier to contracting-out. It is also easier to alter the specifications surrounding transactions thereby reducing delays in communication. Hence, the costs of contracting-out should also decline. More generally, reductions in transaction costs, especially costs associated with identifying, monitoring and enforcing agreements associated with reorganized modes of commercial activity, should facilitate a wide range of new forms of transacting. Beyond contracting-out, they might include increased use of joint ventures and other collaborative arrangements, on both a short-term and long-term basis, as well as more frequent use of consortia to carry out research and development and other activities contributing to technological change.

The impact on dynamic efficiency of changes in underlying competitive conditions is potentially quite complex. For one thing, the relationship between market structure and technological change is uncertain. Specifically, it has been found that a substantial degree of market power is associated with innovation in some industries, while the opposite is true for other industries (Kamien and Schwartz, 1982). Nevertheless, a generalization along the following lines does not seem inappropriate: the threat of entry is a salutary incentive for firms to engage in innovation, especially in technology-intensive industries (*ibid.*). Hence, to the extent that the emergence and growth of e-commerce promotes increased contestability of markets, technological change might also be indirectly stimulated.

Costs of Adoption

UP TO THIS POINT, the discussion has identified the potential productivity benefits associated with e-commerce. It is also important to acknowledge that there will be costs associated with the adoption of e-commerce technology and related commercial practices. Those costs reflect, in part, the real resources expended in order to develop the private and public sector institutions necessary for the effective functioning of e-commerce. An example is the development of an appropriate intellectual property infrastructure to address the unique challenges to private property rights posed by the Internet. Other examples include investments in hardware and software information technology, especially broadband transmission capacity, the development of secure electronic payment systems, including electronic money, the advertising and promotion necessary to inform consumers about the availability of e-commerce opportunities and offerings, and the implementation of tax treaties and protocols to address public policy issues arising from the growth of cross-border commerce.[10]

The costs of adopting e-commerce can be likened to the costs of increased environmental protection. Specifically, even an optimal environmental protection regime will impose costs on the economy, as investments in physical and human capital, as well as variable costs associated with altering production techniques, are required to meet new environmental standards. While the adoption of new environmental standards might well have net benefits for society, the relevant costs are likely to be incurred before most of the relevant benefits are enjoyed. Hence, one must also be concerned about the timing, as well as the magnitude of the relevant benefit and cost streams, in order to estimate the net present value of the standards in question. Similar timing considerations are likely to apply to e-commerce as well.

SUMMARY

> The ease of shopping nationally — or even globally — online frees consumers from dependence on local merchants. Low-cost outlets win additional business and thrive. High-cost sellers shrink and eventually go out of business. At the same time, electronic commerce reduces or even eliminates layers of retail and wholesale, cutting the cost of marketing and distribution.
> (Federal Reserve Bank of Dallas, 1999, p. 16)

THE PRECEDING SECTION provides a broad conceptual framework linking e-commerce to productivity change. The main linkages arguably occur through two channels: 1) reduced transaction costs; and 2) increased competition and contestability. While it might seem excessively reductionist to equate the many potential consequences of e-commerce to these two broad channels, the essential nature of the underlying technology is supportive of this conceptual classification. Specifically, at its core, the Internet is a communications medium. As such, its major impact should be associated with changes in the cost structure of communications. Certainly, reductions in transaction costs are an important expected outcome of reductions in communications costs.[11] Reduced communications costs might also be expected to expand the relevant geographic market of many products, thereby promoting more structurally competitive markets. As a related matter, the substitution of relatively inexpensive communication inputs for relatively expensive physical (e.g. "bricks and mortar"), and non-physical inputs (e.g. stockbrokers) should lower the costs of entry into the relevant markets, especially those characterized by high fixed and sunk" costs.

The linkages between e-commerce, on the one hand, and transaction costs, competition and contestability, on the other, are explored in more detail in the next section.

LINKING E-COMMERCE TO PRODUCTIVITY GROWTH

> With the Internet's arrival, many transaction costs are approaching zero. Large and diverse sets of people scattered around the world can now, cheaply and easily, gain near real-time access to the information they need to make smart decisions and coordinate complex activities.
> (Tapscott, 2000, p. A38)

AS DISCUSSED ABOVE, there appear to be two main interrelated drivers linking e-commerce and productivity growth. One is the reduction in a range of transaction costs that directly or indirectly promotes increased allocative, technical and dynamic efficiency. The other is increased competition and contestability that leads to improvements in allocative and technical efficiency, and likely in dynamic efficiency as well.

TRANSACTION COSTS

IN ORDER TO BETTER ASSESS the potential impact of e-commerce on transaction costs, it is useful to outline the nature of those costs. The costs of transacting are essentially comprised of:

1. *Search costs*: the costs of physically searching for market information related to potential buyers, sellers, product availability, product quality, prices and so forth.
2. *Contracting costs*: the costs of creating and implementing contractual agreements.
3. *Monitoring costs*: the costs of ensuring that contractual commitments are satisfied.
4. *Adaptation costs*: the costs associated with negotiating and implementing changes to contracts over time.[12]

Search Costs

Most discussions of the economic advantages of e-commerce focus on the reductions in search costs resulting from the increased ease with which information about prices, product availability, demand and so forth can be obtained using the Internet. These reductions in search costs would be especially relevant for specialized products for which market participants are few in number and perhaps widely dispersed geographically.[13] As a result, markets for products whose search costs are significantly reduced by e-commerce should become more competitive, since a greater number of market participants, hitherto segmented by geographical space, will compete for favourable terms and conditions. Consequently, product prices should more closely approximate their marginal costs, thereby contributing to improved allocative efficiency.[14] Technical efficiency should also improve as producers in hitherto segmented markets face new competition from outside. Both technical and dynamic efficiency should improve as producers and consumers become better informed about factor input prices and, more generally, about ways to produce and consume more efficiently.

Search Goods

Economists identify a product as a search good if the important attributes of the product can be identified by the consumer prior to purchase. Computer equipment is an obvious example of a search good, as technical specifications are quite meaningful and are easily communicated to potential buyers. Financial securities listed on major stock exchanges are also search goods in that properties such as price, volume, dividend yield and so forth can be readily and easily determined prior to purchase.

Experience and Credence Goods

If the consumer must utilize a product in order to determine key attributes (such as ease of use, durability, etc.), the product is said to have *experience* qualities.[15] An example of an experience good is the automobile. Certain subjective characteristics of an automobile, such as road feel, steering responsiveness and so forth can usually best be established by driving the car.

Critical attributes of some specialized products may not be identifiable with confidence even after utilization. Economists identify such products as *credence* goods. An example sometimes cited is medical services. Since patients will frequently improve independently of the services provided by health care professionals, only fairly prolonged experience with the ministrations of a health care specialist will provide the patient with insight into whether or not the specialist adds significant value to the patient's efforts to be healthy. Moreover, health problems and related concerns are, to some extent, idiosyncratic. Hence, one patient's satisfactory experience with a health care professional may not be a reliable signal for other patients of the latter's likely satisfaction about that professional.

It is widely acknowledged that the Internet is an extremely robust tool for collecting information about search goods. Indeed, the fact that computer equipment and travel and brokerage services have been prominent online purchases during the early e-commerce experience attests to the advantages enjoyed by those selling search-type goods through e-commerce. Since price is an important searchable feature, the emergence of price-searching software will further enhance the advantages of electronic buying and selling of search goods.

The ability to electronically download free samples of certain types of experience goods expands the scope of e-commerce to many of these types of goods as well.[16] For example, music and book publications, software, financial information and advice, and educational courseware, among others, can be downloaded by potential buyers to evaluate products on offer. Increasingly, the Internet will permit portraying product features in a context that approximates personal inspection. For example, three-dimensional software allows potential buyers of real estate to take online tours of the interior of houses. Similarly, buyers of designer clothing can have the fitting done electronically using scanners, and can be provided with pictures of how they will look wearing the designed products.

For experience goods that cannot be effectively sampled electronically, producers can try to reassure consumers about their qualitative attributes in more traditional ways, such as by investing in the creation of brand names, by offering product satisfaction warranties and so forth. In this regard, it is unclear how the Internet, *per se*, will affect the costs that producers need to incur in order to create the trust capital required to make their quality claims credible to potential customers. Traditionally, large accumulated sunk costs in brand names and trademarks have been used by firms to create trust with potential customers (Klein and Leffler, 1981). To the extent that the Internet allows firms to reduce (or avoid) the sunk cost investments traditionally required to market and promote experience goods, consumers may become even more concerned about deceitful marketing practices on the Internet, and the marketing of experience goods through e-commerce may suffer as a result.[17] In this case, it may be incumbent bricks-and-mortar sellers that will succeed in e-commerce by leveraging the credibility of their historic sunk cost investments to build trust on the Internet.

It is also technically possible to distribute credence goods over the Internet. For example, some psychologists are selling their services online to clients, primarily through electronic mail. Medical doctors can also be contacted at Web sites to provide answers to health care-related questions, although diagnoses are usually highly qualified to minimize the risk of litigation. The emergence of relatively low-cost video conferencing is allowing an increasing number of professionals to have face-to-face consultations with their online customers. Nevertheless, an individual's purchase of credence goods is likely to remain strongly guided by recommendations from close contacts such as family, friends and other professionals. Supporting this assertion is the observation that the vast amount of online medical information, to date, appears to be used by patients primarily to bring ideas and questions to their physicians, rather than as a source for identifying the services of physicians (Hafner, 1998).[18]

In summary, the main point of this relatively long discussion of search cost savings applied to different types of products is to highlight the relatively limited *a priori* range of products over which this potentially important consequence of e-commerce is likely to be relevant. Specifically, the search component of transaction cost savings is likely to be most substantial for traditional search goods and relatively inexpensive experience goods that can be electronically sampled. Certainly, the most successful B-to-C product categories, to date, support this assertion. Nevertheless, as consumers become more confident about the security of Internet payment systems, and as the willingness and ability of online merchants and auctioneers to ensure the integrity of their e-commerce offerings grow, the range of products benefiting from lower effective search costs should expand.

Other Transaction Costs

There has been less discussion, and much less of a consensus, regarding the impact of e-commerce on other types of transaction costs. It has been argued that the widespread adoption of standardized electronic contracts will lower the average cost of simple contracting, especially for B-to-B transactions, since a repetitive activity with relatively high variable costs will be replaced by an activity with relatively high once-and-for-all fixed and sunk costs but relatively low variable costs. Indeed, this notion underlies much of the speculation about the large technical efficiency gains associated with e-commerce.

The practical relevance of the claim that the Internet will facilitate a high degree of standardized contracting is uncertain. For one thing, there are unresolved legal issues surrounding the enforceability of e-commerce agreements, although recent legislation points towards some resolution of those issues in the foreseeable future.[19] For another, it is unclear that transactions between parties, including those who regularly do business together, are sufficiently standardized to obviate the need for contract modifications on an ongoing, and perhaps unpredictable, basis. This caveat is especially relevant for international transactions, where differences in legal regimes, contractual customs and so forth may oblige firms to enter into multiple agreements with a resulting loss of opportunities to standardize contracts and other agreements.

To the extent that the perceived risks of opportunistic behaviour are no lower for e-commerce activities than for conventional commercial activities, electronic contracts may need to be as complex and as frequently adapted over time as non-electronic agreements. In this case, the spread of e-commerce may have little direct impact on the costs of writing and enforcing commercial agreements. However, to the extent that the growth of e-commerce significantly expands the relevant geographic markets for certain products, buyers and sellers of those products should experience lower costs when switching transaction partners. Lower switching costs, in turn, should reduce incentives for individual market participants to act opportunistically, all other things constant, which should reduce the costs of establishing, maintaining and enforcing contracts.[20]

Summary

A primary focus of current discussions linking e-commerce to productivity growth is the anticipated reductions in transaction costs. This section has identified, in particular, the strong prospects for a decline in search costs over a range of products. The somewhat lesser potential for substantial reductions in the costs of establishing, monitoring and enforcing simple contracts was also acknowledged. However, it is unclear that transaction costs reductions will be substantial enough to result in relatively large changes in overall economic efficiency. In particular, search costs may be difficult to reduce electronically for many types of products. Moreover, the market attributes that give rise to relatively high costs of contracting may not be attenuated by e-commerce unless the diffusion of e-commerce results in more competitive and contestable product markets. It is to this latter issue that we now turn our attention.

COMPETITION AND CONTESTABILITY

> The Internet is severely curtailing retailers' pricing power by giving consumers the means to compare different offerings with the simple click of a mouse.
> (Casey, 1999, p. A17)

INDUSTRIAL ORGANIZATION ECONOMISTS VIEW COMPETITION as both a structural and a behavioural phenomenon. Structurally competitive markets are characterized by relatively low levels of ownership concentration. That is, the largest sellers (or buyers) in a market enjoy relatively small market shares. Moreover, there are numerous market participants. Behaviourally competitive markets are characterized by vigorous price and non-price competition with rivals largely abstaining from what might be considered "cooperative" behaviour.[21]

Contestability is concerned with the influence that potential entry has on the behaviour of existing competitors. In a contestable market, the threat of entry is sufficiently compelling that incumbent sellers are obliged to behave in a competitive manner, regardless of the existing level of ownership concentration. Indeed, in a perfectly contestable market, the equilibrium price and output rate correspond to those that would obtain under perfect structural competition, even if there is only one seller in the market.

The predominant view of e-commerce is that it will promote increased competition. In particular, as noted above, reductions in search costs are expected to contribute to the expansion of relevant geographic markets that, in turn, should increase structural competition. The latter results from an expansion of the geographical scope over which firms can economically compete.[22]

It has also been suggested that e-commerce will reduce barriers to entry, especially for small firms, thereby enhancing the contestability of product markets. Specifically, it is argued that e-commerce imposes much lower sunk-cost investments on sellers than does entry through more conventional commercial channels. For example, Solomon (1995) asserts that it costs as little as US$1,000 a year to open and run an electronic storefront on the Internet that is accessible by as many as 20 million people. However, the explosive proliferation of Web sites is making it increasingly difficult for sellers to gain visibility on the Internet. In order to reach more easily individuals browsing the Internet, many online merchants are, therefore, using high-traffic search engines, such as Yahoo, as a springboard to their site. The owners of such popular search engine sites, in turn, can be expected to charge listing fees that reflect the commercial advantages they offer.

Established sellers are also attempting to increase their success at e-commerce by using a *bricks-and-clicks* approach to the activity. The latter refers generally to the leveraging of brand names created in conventional marketing channels to promote selling efforts on the Internet. For example, the main online sports Web sites are attempting to increase viewership by cross-promoting with major events that they feature on other media, such as sister cable channels. As another example, Canadian banks are entering the U.S. market through a combination of Internet operations and physical branches (Greenberg, 1999). While it is almost certainly true that marketing through the Internet is cheaper than through purely physical channels, a complementary relationship between the two would presumably mitigate against easy entry by *de novo* firms in many product markets.

This caveat is especially relevant to the extent that costs associated with warehousing and shipping continue to represent a significant portion of the total cost of e-commerce.

Brand name spillovers from conventional distribution and media channels can be expected to increase the sunk costs of entry for *de novo* sellers by requiring the latter to invest substantial amounts of money in creating a unique brand name.[23] This condition is likely to be more relevant for sellers engaged in B-to-C e-commerce than for those engaged in B-to-B e-commerce. Nevertheless, even in the latter case, a reputation as a reliable supplier is usually required to gain access to the purchasing networks increasingly being formed by leading companies in a wide range of industries.[24] In some cases, acceptance into purchasing networks requires would-be suppliers to have an established reputation for reliability or a demonstrated capacity to meet supply commitments. To the extent that such requirements delay smaller entrants in realizing minimum efficient scale and/or oblige new firms to enter on a relatively large scale, with commensurately large sunk costs, e-commerce may be less of a boon to contestability than some early enthusiasts have contended.

In other cases, incumbent firms may be able to use e-commerce capabilities to augment first-mover advantages. An example is American Airlines' program to offer frequent fliers one-to-one marketing software. With this software, preferred customers can streamline their booking process by creating a profile of their home airport, seating and meal preferences and so forth.[25] Another example is the effort of established brokers such as Merrill Lynch to bundle personalized advisory services with online trading as an integrated service offering in response to the emergence and growth of discount online trading services.

Some observers have also argued that we can expect online sellers to implement various strategies to reduce the transparency of prices in order to mitigate competition (Picot, Bortenlanger and Rohrl, 1997). For example, prices on the Internet might be quoted as a basis for further negotiation, rather than as a firm offer that will be filled if the buyer meets the quoted price. In this way, some price discrimination remains possible based upon the buyer's urgency for the product, the opportunity cost of the time she spends haggling over the product and so forth. The use of bundled pricing and complicated charging schedules can also obscure price differences among sellers.[26]

The growth of industry group Web sites might facilitate non-competitive pricing by dominant sellers or buyers who comprise the group. Table 4 lists a number of recently announced group Web sites ostensibly implemented to reduce the costs of purchasing inputs, while Table 5 shows potential cost savings from B-to-B e-commerce in U.S. industries. What is unclear is whether the expected cost savings will come primarily from economies of scale and other real efficiencies, or whether they will be derived from the exercise of buying power on the part of large purchasers.[27] Obviously, only the first source of cost savings is relevant when considering the productivity benefits of e-commerce.

To be sure, in some areas of B-to-B and B-to-C commerce, established multi-product *e-tailers* such as Amazon.com will be competitors to industry group Web sites; however, this source of competition is likely to be less robust, the more technically specialized the set of products being transacted. Likewise, auction sites such as eBay may not be seen as reliable alternatives to industry-run sites for buyers or sellers of products when small deviations from desirable specifications render those products inferior. This is especially likely if Web site participants enjoy well established reputations for reliable product quality and delivery.

TABLE 4

SOME EXAMPLES OF ONLINE GROUP PURCHASING OR SELLING SITES

INDUSTRY	FIRMS INVOLVED
Oil and Chemicals	More than twelve firms including Royal Dutch/Shell and Dow Chemical
Specialty Metals	Eight of world's largest specialty metals firms including Alcoa and Alcan
Personal Computers	Largest PC makers and component suppliers including Compaq, Gateway, and Hewlett Packard
Automakers	Ford and General Motors
Real Estate Firms	Thirteen large commercial property firms
Brokerage Firms	Charles Schwab, Fidelity Investments and two other firms (electronic network to trade stocks)
Railroads	Union Pacific, CSX and two other railroads (to arrange freight transportation for customers)
Lumberyard Chains	Wickes and five other lumberyard chains

TABLE 5

POTENTIAL COST SAVINGS FROM B-TO-B E-COMMERCE IN U.S. INDUSTRIES (PERCENT OF TOTAL INPUT COSTS)

INDUSTRY	COST SAVINGS
Aerospace Machining	11
Chemicals	10
Coal	2
Communications/Bandwidth	5-15
Computing	11-20
Electronic Components	29-39
Food Ingredients	3-5
Forest Products	15-25
Freight Transport	15-20
Healthcare	5
Life Science	12-19
Machining (metals)	22
Media and Advertising	10-15
Maintenance/Repair/Operating Services	10
Oil and Gas	5-15
Paper	10
Steel	11

Source: Coppel, 2000, p. 16.

SUMMARY

WHILE STRONG ARGUMENTS HAVE BEEN MADE in support of the view that the growth of e-commerce will stimulate substantial increases in the competitiveness and contestability of many product markets, theoretical and practical considerations suggest caution. In particular, reductions in required sunk costs of entry may be relatively modest to the extent that substantial investments are required to create brand awareness of new Web sites, as well as to offer security, privacy and other features of importance to online consumers. Indeed, substantial sunk cost investments in physical capital may be required in order to cultivate trust among those consumers. In this regard, existing firms with dominant marketplace positions in conventional distribution channels may enjoy substantial first-mover advantages in bricks-and-clicks competition.

Any evaluation of the potential impact of e-commerce on competition and competitiveness should also recognize the possibility that reductions in information costs may enhance the ability of incumbent sellers to exploit their market dominance more effectively. For example, it may enable those sellers to identify more precisely when they are able to increase price-cost mark-ups profitably. The Internet can also enable sellers to offer new services that are complementary to existing services. Such enhanced capabilities can potentially reinforce existing advantages of incumbency, thereby inhibiting the entry and expansion of new competitors. For example, airlines can utilize data collected on travel patterns and service preferences of customers to target specific promotions, such as seat sales on specific routes, to customers who tend to fly those routes.

In short, the conceptual linkages between e-commerce, competition and productivity growth belie some of the enormous enthusiasm expressed by many early commentators. In particular, it is not clear that e-commerce will prove a major boon to the contestability of markets. While it is not difficult to accept the working hypothesis that e-commerce will promote competition and, therefore, improved productivity in the long run, the magnitude and timing of that link are much more uncertain.

ASSESSING THE LINKAGES

IN THIS SECTION, AN ATTEMPT IS MADE to assess the available evidence on the potential linkages between e-commerce and productivity change. As the analysis presented in the previous sections suggests, the numerous direct and indirect potential linkages make any compartmentalized evaluation of the evidence difficult. Moreover, future changes in technology and public policy can either augment or diminish the strength of these linkages. Therefore, as a basis for reviewing the available evidence, it is useful to list several hypotheses that follow from the more general discussion of efficiency linkages provided above:

1. Reductions in search costs should lead to less market segmentation and increased price uniformity across geographical markets associated with e-commerce.[28]
2. Increased information about demand characteristics should lead to increased multi-part pricing and, possibly, greater price dispersion across different groups of e-commerce market participants. Hence, there may well be conflicting forces influencing the uniformity of e-commerce prices.
3. The lower costs associated with altering electronic prices, as well as improved information about current market conditions should be accompanied by greater flexibility of e-commerce prices.
4. Increased competition should lead to lower prices, on average, for e-commerce transactions.
5. E-commerce transactions should have lower costs as a consequence of the reduction of various intermediation activities; since e-commerce makes it cheaper for final buyers and sellers to interact directly.
6. More timely information about market conditions should allow e-commerce transactions with less need for inventorying. Since inventorying is effectively a means to intermediate between current supply and future demand, this hypothesis is really one aspect of the preceding hypothesis.
7. To the extent that cheaper Internet communications can be substituted for physical inputs, such as printed materials, or for activities such as travel, e-commerce should lead to organizational changes in production that lower costs.
8. Reduced transaction costs should encourage increased contracting-out and other dealings among independent market participants.

PRICING

SOME OF THE EARLIER STUDIES COMPARING PRICES of goods purchased on the Internet to prices of the same products purchased through conventional channels found that the former were, on average, higher than the latter.[29] This result was not entirely surprising given the start-up costs facing new Internet sellers and the small initial sales volumes. Moreover, a problem with these comparisons, which remains to date, is that buyers gain certain advantages of convenience by purchasing on the Internet, and simple price comparisons may fail to take into account the convenience and other implicit cost savings that Internet shoppers enjoy. More recent studies, especially those focusing on products that are intensively purchased through the Internet, find that prices are about 10 percent lower, on average, than prices charged by traditional retailers (Coppel, 2000). However, there is substantial variation across product categories. For example, retail brokerage commissions for online trading have been substantially lower than traditional commission trades, although the latter have decreased substantially in the face of competition from online brokers.[30] On the other hand, there is no indication that the growth of online travel services has led to a decline in average airfares (OECD, 2000).

There are several possible explanations for the broad conclusion offered by the OECD that e-commerce has not led to substantial price changes in most product markets (OECD, 2000, p. 75). One is the previously cited possibility that consumers are paying higher prices online partly for the convenience offered by electronic commerce. A second is that cost savings associated with e-commerce, to date, have been small. A third is that sellers have been able to use better information to charge higher average prices in certain cases so that, on balance, e-commerce prices are not much lower than other prices. This result could be obtained either because some products sold in competitive markets were underpriced as a result of highly imperfect information or because sellers enjoy an enhanced ability to use price discrimination on the Internet.

Unfortunately, there is very little evidence bearing upon the price determination process in e-commerce transactions. Estimates of the impact of e-commerce on costs will be reviewed in the next section. There is some limited anecdotal evidence supporting the notion that sellers can and do charge higher prices for additional conveniences offered through online transacting. For example, Marriott International's prices for hotel rooms booked on the Internet are higher, on average, than those booked offline, in part because unique amenities are offered in the former case, such as maps of tourist attractions and services surrounding Marriott hotels (Schlesinger, 1999). There is also evidence that improved information may lead to higher prices by significantly broadening the demand side of the market for specialized products. This seems to be the case, for example, in book retailing, where the Internet has brought prices down, on average, for common books, but appears to have inflated prices for rare books (Bensinger, 1999).

There is also some evidence to support the assertion that the Internet has not substantially changed competitive conditions in relevant markets. Consequently, a number of anticipated salubrious effects on prices have not yet been realized. For example, the substantial expansion of geographic product markets that some experts anticipated has arguably not yet occurred. A recent survey by

Forrester Research, an Internet consultancy, estimates that 85 percent of online firms are incapable of shipping across borders. It is, therefore, unsurprising to see the estimate that exports beyond national borders account for only about 7 percent of European online retailers' revenues (Coppel, 2000, p. 18).

In this regard, the relevant issue is whether online transactions are intrinsically localized or whether the growth of e-commerce will eventually lead to substantial increases in international e-commerce trade. Obviously, one can only speculate on this matter. However, there is a growing perception among industry experts that regular Internet users prefer to make purchases at domestic Web sites. By dealing with local retailers, consumers can buy products using their own currency and avoid duties at the border. Thus, AltaVista found that when it launched its Canadian Web site, users complained that there were too many U.S. retailers selling their products in U.S. dollars. AltaVista now highlights retailers that sell in Canadian dollars and ship their products from Canada (Evans, 1999a).

It can also be argued that competitive conditions in domestic markets have not been fundamentally altered by e-commerce, except for some industries. As noted in an earlier section, there can be large sunk costs associated with establishing a commercially successful Web site, as well as significant first mover advantages. Forrester Research has suggested that large national merchants enjoy inherent advantages in technology, brand and scale that contribute to their e-commerce success.[31] This tends to be confirmed by survey findings that the majority of small firms do not see profitable opportunities to engage in e-commerce.

Several other empirical observations have been made about online pricing behaviour. As expected, prices tend to change more frequently online, presumably reflecting lower "menu" costs (Coppel, 2000). However, price dispersion is apparently no less online than offline (*ibid.*). From the latter result, one might infer that there is much more customization of pricing on the Internet, but this is apparently not the case. For example, the OECD (2000, p. 74) reports that among the 100 largest firms engaged in B-to-C e-commerce, less than 1 percent dynamic price negotiation or customization was present in one form or another in less than 1 percent of cases. This latter finding, combined with the observation about price dispersion on the Internet, suggests that, to date, the efficiency of the pricing mechanism has not been significantly improved by e-commerce. Two additional observations are relevant in this regard. One is that, of the previously mentioned sample of the 100 largest firms, about half displayed no price information on their Web sites. A second is that less than 5 percent of these firms listed prices of competing products (OECD, 2000).

COSTS

WHILE THERE ARE A RANGE of potential direct and indirect transaction costs savings associated with e-commerce, as noted above, it has been suggested that the evidence on cost impacts can be summarized with reference to three broad categories: 1) the costs of executing sales; 2) the costs associated with procuring production inputs; and 3) the costs associated with making and delivering products (Coppel, 2000).

Costs of Executing a Sale

These costs encompass a set of activities including the establishment and maintenance of a point-of-sale, order placement/execution, customer support, after-sale service, and staffing.

As noted in an earlier section, the cost of establishing a Web site can vary widely depending upon the features of the site, how much promotion is done and so forth. Thus, one sees estimates ranging as widely as $20,000 to hundreds of millions of dollars (OECD, 2000, p. 59). This range makes it difficult to compare the cost of establishing a Web site to the cost of establishing a physical point-of-sale. Nevertheless, the general consensus is that it is less expensive to maintain an electronic storefront than a physical one, primarily because the former has few variable costs and eliminates duplicate inventory costs. Reliable estimates of the relevant cost differences are, however, unavailable.

The dissemination of online information enables consumers to be better informed about relevant attributes of the purchasing activity. This, in turn, reduces the expenditures firms must incur to inform consumers about the availability of products, relevant product features and so forth. Some estimates of the cost savings associated with online order placement and execution exist. For example, Micron Computers reports a productivity gain of a factor of ten. Specifically, their Web sales people spend, on average, two minutes on the telephone with customers who have looked at their Web site, but 20 minutes with traditional customers (OECD, 2000, p. 60). Auto dealers claim similar gains. They report spending about $25 to deal with an e-commerce bid, but several hundreds of dollars for a face-to-face transaction. Of course, these estimates ignore the costs assumed by consumers to obtain online information, including productive time lost at work.[32]

Estimates are also available on the cost savings associated with using the Internet to provide customer support and after-sale services. For example, Cisco Systems has moved 70 percent of its customer support online and claims to have saved over $500 million, or 17 percent of its total operating costs on that activity. Estimates by Forrester Research show savings of a much larger order of magnitude. The firm estimates that it generally costs $500 to $700 to send a service representative into the field, $15 to $20 to handle a customer question over the telephone, and about $7 per client to set up and maintain an Internet-based customer service system.

Yet another source of cost savings is the reduction in required staffing levels associated with executing sales. Again, the limited sources of evidence are largely anecdotal. For example, Federal Express reports that its online customer service system has obviated the need for some 20,000 new hires, or about 14 percent of its total work force.

Procurement of Production Inputs

By reducing the time required to carry out the purchasing cycle for inputs, online buying allows firms to economize on inventory. It also reduces staffing requirements to carry out that function. According to a study by Goldman Sachs, as cited in Coppel (2000), the relevant cost savings range between 2 and 40 percent of the total costs associated with this activity depending on the industry. This range encompasses a more specific estimate of cost savings in purchasing inputs through e-commerce of 30 percent for a consortium of oil and chemical companies (Bahree, 2000). It also encompasses Quaker Oat's estimate that bidding for food ingredients, packaging and services online has led to savings of around 14 percent in the costs of procuring inputs (Hof, 2000). It is unclear whether all of these estimated cost savings reflect real resource savings rather than enhanced market power associated with coordinated purchasing through the Internet.

Distribution

For products that can actually be delivered through the Internet, large cost savings, on the order of 50-90 percent, can be anticipated compared to delivery though conventional channels (OECD, 2000, p. 64). For tangible goods that still require physical distribution, e-commerce methods are estimated to reduce administrative support costs by over 25 percent. Direct distribution over the Internet also reduces the conventional costs associated with intermediation. The OECD (2000, p. 65) estimates that there will be disintermediation cost savings of around 14 percent at the wholesale level and of 25 percent at the retail level, for total cost savings of around $2 trillion. At the same time, there will be new forms of intermediation associated with e-commerce whose costs should be set against the savings associated with the contraction of traditional intermediation activities.

Summary

THE WIDE RANGE OF COST SAVINGS ESTIMATES, as well as the limited number of such estimates, make it impossible to draw any inferences confidently, other than to suggest that e-commerce is likely to lead to significant cost savings in specific economic activities. The impact on productivity growth will, in turn, depend upon whether the cost savings are largely continuing, rather than once-only, and on the growth of sectors that are strongly impacted by e-commerce relative to sectors that are less impacted.

The OECD (2000, p. 72) offers an economy-wide estimate of total cost savings associated with the adoption of e-commerce for OECD member countries. Specifically, it estimates that economy-wide costs will be reduced by about one-half to two-thirds of a percentage point. The OECD suggests that these cost savings are a proxy for total factor productivity (TFP) gains. Since annual TFP growth averaged only around 0.8 percent for the G-7 economies over the period 1979-97, the OECD's estimated impact of e-commerce on productivity is relatively substantial. Moreover, it is suggested that the estimated productivity gains are probably conservative, since they do not account for the welfare gains associated with increased customer choice and a closer matching of consumer tastes and preferences to product availability.

It might be noted, in passing, that the growth of e-commerce could stimulate investments in modern information technology, which should promote improved productivity. While the precise contribution of modern communication infrastructures to productivity growth is subject to some disagreement, the preponderance of the evidence supports the notion that it has been significant (Schreyer, 2000).

POLICY ISSUES

A NUMBER OF FAIRLY FAMILIAR POLICY ISSUES arise in the context of the linkage between e-commerce and productivity. The issues bear upon the magnitude of the gross benefits from the spread of e-commerce, as well as the costs associated with its implementation.

INTERNATIONAL AGREEMENTS

A SIGNIFICANT PORTION OF THE ECONOMIC BENEFITS from e-commerce derives from the expansion of geographical markets. The effective expansion of geographical markets internationally, in turn, will depend upon the legal regime surrounding both the technology platform over which e-commerce transactions take place, as well as the economic activities significantly affected by e-commerce. While the electronic marketplace is currently free from explicit trade barriers, the infrastructures that make e-commerce possible are still burdened by a myriad of trade and investment barriers. Notable sectors include telecommunications, financial services and distribution.[33]

Of particular concern for Canada, in this regard, are direct and indirect foreign ownership restrictions in sectors such as basic telecommunications, banking, and air transport. To the extent that capital investments in these key sectors are essential to facilitate efficient e-commerce transactions, foreign ownership restrictions may constrain the diffusion of e-commerce activities in Canada by discouraging domestic access to the package of technology and skills typically bundled into the capital investments made by multinational companies.

While the issue of foreign ownership is an old one in the Canadian policy context, it is relatively new in the international context as applied to service industries such as telecommunications and banking. Moreover, e-commerce is a service that cuts across these and other traditional service industry classifications. As such, there would seem to be an important policy issue about how e-commerce should be treated under existing international commitments. To the extent that Canada wants to maintain its protection of domestically owned telecommunications and financial services firms, for example, it might be preferable to treat e-commerce as an activity covered under the General Agreement on Trade in Services (GATS), which would make its treatment less liberal than under legislation dealing with trade in goods. The main point here is that Canadian policymakers may want to reconsider the broad range of sectoral policies restricting foreign ownership and participation in domestic economic activities in light of the potential for those policies to mitigate the economic benefits of e-commerce.

International agreements in other related areas are also increasingly seen as necessary to promote the adoption and effective use of e-commerce. Examples include laws and regulations governing privacy and the security of transactions on the Internet. These issues have been extensively discussed elsewhere and will not be revisited here. It seems innocuous to recommend that Canada participate actively in international forums devoted to addressing these issues. Less innocuous is the issue of whether the optimal forum for addressing these issues is at the multilateral level or the regional level. Given the overwhelming degree to which Canada's economy is integrated with the U.S. economy, it might be argued that negotiations surrounding the international regulatory and legislative framework for e-commerce would most fruitfully be conducted on a bilateral basis, especially given the extensive lead that the United States and, to a lesser extent, Canada enjoy in online transacting.

Competition Policy

AS NOTED EARLIER IN THIS REPORT, a variety of cooperative arrangements are being pursued by leading firms in a wide range of industries to leverage the benefits arising from jointly operated Web sites. Concerns have been expressed that such arrangements might facilitate price coordination in buying, or selling, products, as well as create or accentuate barriers to entry for suppliers who are denied access to industry Web sites.

While it is certainly not obvious that existing competition policy legislation and jurisprudence are insufficient to deal with competition problems arising from e-commerce activities, the nature of the cooperative agreements being promulgated fall into a policy area that has not been actively dealt with to date. Namely, cooperative agreements, including joint ventures, have not yet been the subject of close and active scrutiny under Canada's competition policy framework. It might therefore be useful to examine the potential competitive implications of such agreements with a view towards identifying whether and how traditional policy criteria and remedies may need to be adapted to address changes to the business practices environment brought about by e-commerce. To the extent that cooperative arrangements involve Canadian and U.S. firms as some already do, in metals for example, increased intersections between U.S. and Canadian competition policy initiatives might be anticipated. Therefore, an examination of the conceptual and practical issues raised by increased cross-border cooperative business practices through e-commerce activities might also be warranted.

AGGLOMERATION ECONOMIES AND DOMESTIC INDUSTRIAL POLICIES

WHILE NOT EXPLICITLY DISCUSSED IN THIS REPORT, the general opinion expressed in the relevant literature is that the growth of e-commerce is a force for dispersing the geographical concentration of economic activity that has been observed in a wide range of industries, including modern service and high technology industries.[34] In fact, there has arguably been very little reliable evidence produced to confirm or deny the generalized validity and significance of this hypothesis. Given the existing regional differences in the concentration of higher value-added activities in Canada, the potential role that e-commerce might play in augmenting, or mitigating, those differences is a potentially important policy issue. It might thus be useful to undertake a number of careful case studies of specific economic activities, such as financial services, that have already been substantially impacted by e-commerce. The case studies would presumably focus on whether and how the growth of e-commerce has influenced the geographical distribution of specific activities comprising an industry's value chain.

CONCLUSION

AT THIS RELATIVELY EARLY STAGE, one can only speculate about the economic impacts of e-commerce, including its effects on industrial productivity. Nevertheless, it can be argued at this point in history that theory and early evidence point to the likely economic consequences of e-commerce as being evolutionary rather than revolutionary. In this regard, there is, in my view, a real danger that public policies will tilt unduly towards promoting directly or indirectly Internet-based business activities while failing to recognize the costs imposed on conventional economic activity. For example, subsidies provided to so-called *dotcom* companies may have the unintended consequence of increasing resource costs and otherwise disadvantaging traditional wholesalers, retailers and other offline sellers.[35] Unless productivity spillovers from e-commerce are significantly larger than those from conventional forms of commerce, there may be little theoretical justification for promoting e-commerce as a public policy goal. This is especially so given the documented and substantial deadweight costs associated with government tax and subsidy programs. To date, the economic case for emphasizing the promotion of e-commerce is speculative.

ENDNOTES

1 A closely related definition identifies e-commerce as covering every type of business transaction in which the participants prepare or transact business or conduct their trade in goods or services electronically. See OECD, 2000.

2 To the extent that B-to-B transactions are 5 to 6 times greater than B-to-C transactions, the value of B-to-B e-commerce would be around US$30 billion. See Mann, 2000.

3 Available evidence suggests that e-commerce is an even smaller phenomenon in other developed countries, including Canada. For example, e-commerce sales in Canada for 1999 are estimated to be only around 3 percent of all North American e-commerce sales. See Evans, 1999b.

4 See "Is That E-commerce Roadkill I See?," *Business Week*, September 27, 1999, p. EB96.

5 See "A Hard Sell Online? Guess Again," *Business Week*, July 12, 1999, p. 142.

6 See "Internet Retail Activity by Canadians," *The Globe and Mail*, January 28, 2000, p. E5.

7 We abstract here from considerations of "second-best" and other qualifications. For purposes of this report, such considerations are unnecessary.

8 Real output, in this context, conceptually encompasses quality improvements (including enhanced variety) that are associated with improved consumer welfare.

9 Such reorganizations can, in turn, give rise to improvements in allocative and technical efficiency.

10 Many of these social infrastructure costs are discussed in detail in Mann, 2000.

11 The precise nature of the potential relationship between the two phenomena will be considered in more detail in the next section.

12 This categorization of transaction costs is discussed in Wigand, 1997. An important component of search activity is the verification of the claimed attributes of products. Where it is difficult for producers to validate their product claims, markets may be

characterized by a "lemons" problem, and reliable producers may be driven from the market. For a discussion of this phenomenon on the Internet, see Lu, 1998.

13 Collectibles, such as rare books, are obvious examples of this type of product.

14 It has also been suggested that electronic commerce facilitates more complex pricing arrangements that, in turn, could allow sellers to employ more efficient multi-part pricing schemes.

15 A brief discussion of the distinction between search and experience goods is found in Carlton and Perloff, 1994, pp. 596-8.

16 The phenomenon also raises concerns about appropriation of intellectual property on the Internet, as the recent case involving Napster illustrates. The costs associated with public and private sector efforts to address those concerns are part of the costs of adopting e-commerce as noted in an earlier section of the report.

17 This point is also made in Lu, 1998.

18 To be sure, treatment protocols of some health care providers may be improved by the information that is brought to them by patients. As well, health professionals may find it cheaper and more convenient to search for information on the Internet than through traditional sources such as journals and medical society publications. The use of the Internet to access health care information has grown dramatically. For example, one recent estimate asserts that half of all consumers who access the Internet are seeking health-related information (Tyson, 2000).

19 For example, recent U.S. legislation affirms that electronic "signatures" are as binding as non-electronic signatures on legal contracts.

20 For an extensive discussion of how the transaction costs of commercial outsourcing are affected by environmental features such as competition, see Vining and Globerman, 1999.

21 Cooperative behaviour is also sometimes characterized as "conscious parallelism." For a discussion of this type of behaviour, see Greer, 1992, pp. 394-9.

22 For an enthusiastic statement of how e-commerce spells the end of geography and borders as industrial organizational constructs, see Kobrin, 1995.

23 According to some estimates, it costs a minimum of US$100 million to launch a commercially viable Web site. This includes off-line advertising. See Sarkar, 2000.

24 Relatively recent examples of large firms establishing Web sites to engage in combined purchasing and/or selling are provided in Table 4.

25 See "Now It's Your Web," *Business Week*, October 5, 1998, pp. 164-78.

26 Suppliers can also search the Internet to see the availability of substitute products and, subsequently, increase prices when they identify a limited availability of substitutes. See Schlesinger, 1999. For a discussion of computerized "smart pricing," see "The Power of Smart Pricing," *Business Week*, April 10, 2000, pp. 160-2.

27 The potential for members of buying groups to coordinate their selling prices is also a relevant risk in some cases.

28 The assumption that all other things are held constant is implicit in each hypothesis.

29 For an extensive review of available studies, see Coppel, 2000.

30 One estimate is that the average brokerage commission in the United States will plummet from around $80 per trade in 1998 to around $30 per trade in the next year or two (Buckman, 1999).

31 See "E-commerce Seen as No Boon to Small Business," *The Globe and Mail*, July 29, 1999, p. B12.

32 One report recently proclaimed that "cyberloafing" accounts for 30 to 40 percent of lost worker productivity and estimates the price tag at $54 billion annually. As a result, most major companies are recording and reviewing their employees' electronic communications. This monitoring, in turn, imposes its own real costs. See "Workers, Surf At Your Own Risk," *Business Week*, June 12, 2000, p. 105.

33 For a more detailed discussion of these barriers, see Mann, 2000.

34 A review of the theory and evidence on this matter is provided in Globerman, 2001.

35 Surveys show that, to date, e-commerce sales have largely come at the expense of sales made by physical stores or mail catalogues. See, for example, "Is that E-commerce Roadkill I See?," *Business Week*, September 27, 1999, p. EB96.

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20

The Location of Higher Value-added Activities

EXECUTIVE SUMMARY

THE PRIMARY PURPOSE OF THIS REPORT is to identify and assess the implications of industrial clustering for the future location of technology- or knowledge-intensive activities in North America. A related purpose is to identify and discuss potential initiatives that might be pursued in Canada to blunt or reverse the advantages that specific regions in the United States enjoy as a consequence of hosting already established clusters of innovative firms and skilled and entrepreneurial individuals.

The concern of policymakers in small, developed countries like Canada that trade liberalization will encourage productive resources to migrate to larger economies has been somewhat diminished by evidence showing that trade liberalization increases intra-industry trade and international integration instead of reducing the overall level of economic activity. However, as firms rationalize production across geographic locations to take advantage of the horizontal and vertical value chains, policymakers have become more concerned about the nature of economic activity encouraged by specialization and "agglomeration economies." Since knowledge-intensive activities draw more heavily upon human capital than physical capital and social infrastructure that can be created anywhere, the challenge for Canada, competing against the inherent size advantage of the United States, is to create attractive opportunities for industrial clusters. The increased ease of doing business across borders might facilitate the relocation of existing technology-intensive activities from Canada to the United States, especially if agglomeration economies in those activities favour locating in the latter country.

Closer economic integration may affect the mix of value-added activities in Canada by altering the size of industries in Canada and the strength of firms with different mixes of value-added activities within industries, or by altering

the optimal mix of value added within firms in response to international comparative advantage, competitive pressures and the changing economic environment. That is, firms will alter their geographical location in response to closer economic integration, holding constant their industrial focus, size and so forth. Whether this will reinforce the U.S. advantage in products that are human capital-intensive and the Canadian advantage in resource-intensive industries will depend on the degree to which inter-industry trade patterns are affected by closer economic integration and whether existing industrial clusters are characterized by economies or diseconomies of scale.

The location of clusters is not fixed; they expand and contract geographically, and can emerge in locations distinct from the areas encompassing older clusters. While economists are in disagreement on whether historical accidents or the antecedent conditions of a region play a larger role in determining the geographical location of a cluster, several causes have been suggested to explain the benefits of agglomeration arising through external economies of scale. Firstly, a large industrial centre offers a pooled market to workers with specialized skills, creating liquidity in the labour market, which benefits both workers and firms. Secondly, a large industrial centre provides specialized non-traded inputs in greater variety and at lower cost. Thirdly, clusters promote technological transfers and spillovers as closer geographical proximity improves communication. However, too dense a cluster of economic activity creates congestion and diminishing returns.

As well, more research is required to determine whether a region's institutional characteristics impact on the formation of agglomeration economies, and what role government policy can play in promoting clusters. The evidence on whether clusters benefit more from a large number of small firms, which are more likely to contract out, or from the hub-and-spoke model associated with a small number of large firms, is unclear. What is clear is that vertical disintegration of economic activity contributes to the critical mass of specialized business and technical services required to encourage and sustain industrial clusters. But it is not clear that foreign participation in a local economy discourages the formation of vertical and horizontal linkages locally by centralizing innovative activity in the home country, or that foreign affiliates are increasingly dispersing value-added activities to exploit differences in location advantage and local technical expertise. It may be that the forces influencing clusters are dependent on the type of economic activity and industry involved. Low taxes and generous subsidies are obviously preferable for firms and high-skill workers when choosing a location. Fiscal incentives aimed at individual firms are inefficient; a more promising route is to use tax breaks and subsidies to make a region more attractive to a variety of technology-intensive firms. Of course, a satisfactory level of telecommunications and transportation infrastructure, public utilities and other social infrastructures are necessary to sustain an industrial cluster, but not in and of themselves sufficient.

The strength of local competition, including openness to foreign ownership, and the presence of sophisticated customers in a region might improve the nature and importance of external economies of scale. Public policy can nurture a competitive industrial environment and facilitate the migration of labour and skills. Making knowledge-intensive sectors relatively free of regulatory barriers should be the starting point of any coordinated set of government policies aimed at making Canadian regions attractive as locations for knowledge-intensive clusters. Secondly, government policies should promote international labour mobility, especially for skilled professional and technical workers, and for Canada's major urban areas in order to attract industrial clusters.

More importantly, the evidence shows a positive relationship between university research, centres-of-excellence, and a region's innovative performance. This relationship is strongest in larger metropolitan centres with a concentration of high-technology production and established linkages between researchers and the business and financial communities. Thus, government policy will be most effective when focused on "pre-competitive" research, as private firms are easily able to draw on non-local experts for specific, codifiable functions.

Finally, it has been hypothesised that electronic commerce will reduce some costs dependent on physical proximity, and thus reduce the importance of clusters, though this outcome is far from clear.

In conclusion, the paper states that governments should focus less on industrial policy, whereby they target "desirable" industries or "national champions," and instead encourage clusters by promoting conditions within regions that contribute to the realization of external economies. Governments may need to be involved in rationalizing the competing claims of regions for public support. It may be ineffective for a small, open economy to encourage more than one cluster to develop in specific industrial areas. Cooperation would mean allowing and encouraging patterns of regional specialization that maximize the nation's welfare, rather than that of individual provinces. The federal government might justifiably see its role as assisting provincial governments to enhance the specific environment of regional clusters in policy areas where the federal government is dominant. It may well be that the effective promotion of knowledge-intensive clusters in Canada requires a substantial reorganization of government responsibilities and financing arrangements.

INTRODUCTION

> The enduring competitive advantages in a global economy are often heavily local, arising from concentrations of highly specialized skills and knowledge, institutions, rivalry, related businesses and sophisticated customers in a particular nation or region.[1]

A TRADITIONAL CONCERN ABOUT TRADE LIBERALIZATION is the distribution of capital investment. Specifically, policymakers are concerned about net outward investment being undertaken by businesses as a result of reduced tariff and non-tariff barriers to cross-border trade.[2] For policymakers of small, developed countries, a particular concern is that production capacity will migrate to larger countries in a regional free trade area given the existence of (incompletely exploited) economies of scale and scope in firms and industries located in the latter. All other things constant, producers would presumably prefer to be located closer to the major markets for their products in order to save on transportation costs.[3] Hence, with the reduction, or removal, of trade barriers, there should be a stronger incentive for firms to establish or expand capacity in the relatively large geographical markets they serve, especially if economies of scale at the plant and firm levels can be more fully exploited.

Of course, location preferences are shaped by a host of factors, and proximity to major markets may not be the most important. Indeed, economies of product specialization provide an important rationale for encouraging vertical and horizontal specialization of the value chain across plants and affiliates within a multinational corporate structure.[4] The prominence of intra-industry trade underscores the empirical importance of vertical and horizontal product specialization. In particular, the overwhelming evidence is that regional and multilateral trade liberalization has been associated with increased intra-industry trade rather than inter-industry trade.[5]

The association of increased intra-industry trade with closer international economic integration substantially mitigates concerns about individual countries or regions suffering (or enjoying) large net losses (or gains) in capital investments (and associated employment) as a consequence of businesses relocating elsewhere. Rather, the major vehicles for carrying out international trade, that is multinational companies (MNCs), appear to exploit reduced barriers to trade by seeking greater specialization of economic activities. In this context, trade liberalization can be seen as augmenting other economic and technological forces, such as outsourcing and contract manufacturing, which are promoting specialization among economic agents.

While the predominance of intra-industry trade should reassure policymakers that economic integration is rarely followed by a giant sucking sound created by capital and jobs fleeing one region for another, there is less conventional wisdom about the nature of specialization associated with trade liberalization. In this regard, concerns about the overall volume of economic activity are being replaced by concerns about the nature of economic activity encouraged, or discouraged, by economic integration. In particular, an emerging policy concern in Canada, and in some other relatively small countries like Sweden, is that higher value-added activities are being relocated within regional trade areas from smaller to larger countries because of agglomeration economies.

The essence of this latter concern is illustrated by the following quote: "Companies move to the United States, not just because it is the world's biggest market with the lowest taxes and fine golf courses. They move also because globalization is creating groupings or clusters of like-minded companies. Most of the clusters happen to be in the United States and are growing amoeba-like, by the minute. Canada has none, which is why it stands an excellent chance of losing the globalization war."[6] It should be acknowledged that the preceding quote is taken out of context. Specifically, the author does not mean to imply that all economic activities are relocating from Canada to the United States. Rather, he is suggesting that technology-intensive activities are predominantly located in specific regions of the United States, and that North American economic integration is continually reinforcing this pattern. To the extent that innovation ultimately underlies the creation of economic value along the value chains of many goods and services, one might talk about technology-intensive activities and higher value-added activities interchangeably.

While an equation between innovation and value-added activities is, at best, misleading, the relevant policy concerns of small, open economies such as Canada certainly feature a desire to attract and retain more *new economy* production activities.[7] For critical stages of the value-added process in the relevant sectors, such as microelectronics, biotechnology and pharmaceuticals, software design and development, as well as rapidly growing service sectors such as finance, insurance, and business consulting, innovation associated with the application of specialized human capital is crucial. Another way of putting it is that knowledge work underlies the creation of economically valuable output in the *new economy* production activities.

There is abundant and increasing empirical confirmation of the importance of the clustering phenomenon. While clustering characterizes a wide range of economic activities, it is argued to be especially prominent in knowledge-intensive economic activities.[8] Moreover, technology clusters are also characteristic of sectors that are integrated into the global economy, particularly since these clusters attract foreign direct investment.[9] The clustering of technology-intensive electronic industries in Silicon Valley and Boston is one prominent example. The clustering of innovative financial services in New York City is another. The agglomeration of biotechnology companies in San Diego and pharmaceutical companies in New Jersey are also good examples.

Given the predominance of the United States as a locus of regional clustering for knowledge-intensive activities across a range of *new economy* sectors, closer economic integration with the United States might raise concerns about a resulting de-skilling and technological downgrading in comparable Canadian sectors. Specifically, the increased ease of doing business across borders might facilitate the relocation of existing technology-intensive activities from Canada to the United States, especially if agglomeration economies in those activities favour locating in the United States, at the margin. Equivalently, it might be more difficult for Canada to attract its proportionate share of new investment in technology-intensive activities if agglomeration economies continue to be important in those activities.

The primary purpose of this report is to identify and assess the implications of industrial clustering for the future location of technology- (or knowledge-) intensive activities in North America. A related purpose is to identify and discuss potential initiatives that might be pursued in Canada to blunt or reverse the advantages that specific regions of the United States enjoy as a consequence of hosting already — established clusters of innovative firms as well as skilled and entrepreneurial individuals.

The report proceeds as follows. The next section describes the known motivations for clustering, including the potential influence of regional economic integration. The following section discusses the available evidence on the relative importance of different factors that encourage or discourage clustering. The subsequent section identifies and evaluates alternative public policy instruments to enhance Canada's attractiveness for locating innovation-intensive activities. The final section contains a brief summary and our conclusions.

MOTIVATIONS FOR CLUSTERING

> Where dynamic industrial clusters locate is part luck and part accident.[10]
>
> The key characteristic of industrial districts that leads to geographic clustering is that the firms in an industrial district are closely linked in developing new products and production processes.[11]

DISCUSSIONS OF THE MOTIVATIONS FOR INDUSTRIAL CLUSTERING can be found as far back as the writings of Alfred Marshall. Nevertheless, as the preceding quotations suggest, the origins of observed patterns of industrial clustering remain as contentious as the origins of life on earth. Prominent economists such as Gary Becker and Paul Krugman assign an important role to historical accident as a determinant of where a cluster will originally develop.[12] Others suggest that prime movers of industrial clustering can be systematically identified with sufficient attention to antecedent conditions in a region.[13] In particular, the recent literature emphasizes a region's underlying capacity to innovate.

External (Agglomeration) Economies

WHATEVER THE ORIGINAL ROLE OF LUCK OR ACCIDENT, several broad economic characteristics of a geographical region may give rise to so-called external economies of scale which, in turn, underlie the advantages of agglomeration. There are three main sources of external economies: 1) A large industrial centre offers a pooled market for workers with specialized skills, which benefits both workers and firms. 2) A large industrial centre provides nontraded inputs specific to an industry in greater variety and at lower cost. 3) An industrial centre generates technological spillovers, because information flows locally more easily than over great distances.[14]

With respect to the first source of external economies, the basic notion is that a relatively large market for specialized skills will be a more liquid market. That is, individual buyers and sellers of specialized skills can be relatively confident that they will be able to acquire new workers, or new sources of employment, at prevailing wage rates within a short time period. The subsequent reduced risks of excess supply and demand, in turn, make it effectively cheaper for would-be employers and employees to participate in larger labour markets.

The positive relationship between the size of a market and the degree of economical specialization of factor inputs within that market is well known. As economists from Adam Smith to George Stigler have noted, specialization is a function of the breadth of a market. To the extent that specialized inputs are more productive than non-specialized inputs, productivity levels of input users will be higher in larger markets than in smaller markets, all else constant.

Finally, geographical limitations on the scope for technological spillovers derive from the advantages of face-to-face contact in facilitating technology transfers. In particular, a shared information context with end-users often requires a physical presence near customers.[15] A recent issue is whether the emergence and growth of the Internet has obviated the advantages of geographical proximity in the promotion of technological diffusion. Preliminary evidence on this point will be considered in a later section.

While there is broad acceptance of the relevance of these three factors to patterns of industrial agglomeration, there is much less agreement on how the importance of each factor changes with the growth of an industrial cluster. For example, at what point do decreasing, and even negative, returns to clustering set in? Perhaps the major source of external diseconomies in a regional cluster is congestion in its various guises. For example, limited land space implies that housing costs will increase significantly with the growing density of economic activity in a region. Higher housing costs, in turn, will require higher wages and other forms of compensation to attract and retain skilled labour inputs. Other costs of doing business related to the use of land will also rise with increased intensity of usage. Amenities such as green space, short commuting times, and relatively low crime rates are also likely to be negatively related to geographical clustering, at least beyond some point.[16] At issue is the importance of such external diseconomies of scale at different stages of clustering.

As well, relatively little systematic attention has been paid to environmental and institutional factors that might condition the nature and extent of external economies (or diseconomies) of scale. One potential factor is the size distribution of firms within a region. For example, it is often suggested that external economies of scale are especially significant when a cluster consists of a large number of relatively small firms, as might be exemplified by Silicon Valley. Alternatively, it is sometimes argued that external economies are equally or more significant in regions where a few very large firms dominate the local economy, as might characterize the Puget Sound region.[17] Another potential factor is the industrial composition of the cluster. As noted above, while clustering seems to be a phenomenon that is relevant to a wide range of industrial activities, it is implausible that the forces influencing clustering are equally relevant to all economic activities. For example, local access to specialized technical and scientific skills is unlikely to be equally important to the biotechnology and steel industries.

A third factor potentially conditioning the importance of agglomeration economies is the extent of foreign participation in the local economy. It might be argued that MNCs derive fewer benefits from clustering than do smaller, domestically owned firms. This is because MNCs might be able to realize many of the benefits of close proximity to specialized inputs and sources of technology by establishing efficient internal markets in order to transfer specialized inputs among their foreign affiliates. As a result, the presence of MNCs in a region may discourage the deepening of vertical and horizontal linkages among firms that could contribute to the realization of external economies of scale. On the other hand, MNCs may locate in a region precisely to participate in the industrial networks that cluster in that region, thereby actively contributing to the agglomeration process and its resulting economic benefits.[18]

Yet another potentially important set of conditioning factors is associated with public policies that may promote the emergence and growth of regional clusters. Suggested policies include efforts to improve industrial infrastructures, such as roads, ports and airport facilities, as well as expenditures on social infrastructures such as schools, hospitals, police and fire services, access to courts of law, and so forth. Taxes and government subsidies to business have also been identified as important determinants of the location choices of firms.

While most of these factors are discussed in the literature, assessment of their individual importance has been relatively *ad hoc*, and there is some (perhaps unsurprising) inconsistency across the available findings.[19] One possible explanation of some of the inconsistency across studies is that the impact of specific government policies may vary for different economic activities.

Finally, the openness of an economy might condition the nature and importance of external economies of scale. One aspect of openness, as noted above, is the extent to which foreign direct investment is regulated or constrained. A second is the degree to which foreign and domestic competition serve to stimulate and nurture a competitive industrial environment. To the extent that openness to foreign competition is especially important, barriers to import competition may ultimately discourage the creation of an environment that attracts and sustains clustering. However, the venerable infant industry argument suggests that temporary and measured protection from foreign competition might facilitate the incubation of local industrial clusters. A third aspect of openness is inward and outward migration of skilled professional and technical workers. A current concern of policymakers in Canada is that an increasing number of highly skilled Canadians are migrating to the United States under NAFTA visa arrangements.[20] At the same time, there is a substantial flow of skilled workers entering Canada from outside of North America. At issue is whether immigration patterns are, on balance, supportive of or detrimental to the ability of technology-intensive firms to operate in Canada.

ECONOMIC INTEGRATION AND CLUSTERING

AS NOTED ABOVE, Canadian policymakers have long been concerned with the issue of whether closer economic integration with the much larger and dynamic U.S. economy contributes to a hollowing out of Canadian industries, especially those involved in technology-intensive activities. While the hollowing out concept is loosely used and, therefore, imprecise, the basic phenomenon it is meant to describe is the movement of value-added activities abroad.[21]

There are a number of direct and indirect potential linkages between closer economic integration and the location of value-added activities. Since most international production is carried out by MNCs, the relevant linkages are, perhaps, most conveniently discussed with reference to the firm-level strategies of MNCs. In this context, closer economic integration can be broadly thought of as easier and/or less costly mobility of goods, services and factors of production across national borders. It is immaterial whether closer integration is the outcome of a formal trade agreement, such as the NAFTA — which reduced barriers to trade, as well as regulatory and legal barriers to the movement of capital and labour within North America — or of technological developments, such as improvements in transportation and communications.

In a stylized manner, we can characterize Canada's industrial sector as a mix of value-added activities distributed across a set of firms. The firms, in turn, are distributed across a set of industries. Conceptually, closer economic integration can alter the mix of value-added activities in Canada in one of three possible ways: 1) It can alter the relative size of different industries, which, in turn, will alter the mix of value-added activities, assuming that mix differs across industries. 2) It can alter the relative size of firms within industries, which will alter the mix of value-added activities if the mix differs across firms within industries. 3) It can alter the optimal mix of value-added activities within firms, within industries. That is, firms, holding constant their industrial focus, size and so forth, will alter the geographical location of different activities in response to closer economic integration.[22]

Consider the first potential link. In theory, freer trade should lead to the expansion of domestic industries that enjoy a comparative advantage, and to the contraction of domestic industries that have a comparative disadvantage, other things constant. In the case of Canada, an overwhelming portion of its trade is carried out with the United States. Empirical studies have documented that the United States enjoys a revealed comparative advantage in products that are human capital-intensive, especially products that intensively utilize scientific and engineering human capital. Canada enjoys a comparative advantage in products that are resource- and physical capital-intensive. The inference one might draw is that closer economic integration with the United States should lead to relatively less technology-intensive activities in Canada, as technology-intensive activities in Canada contract and other activities expand. The practical relevance of this inference ultimately depends upon two factors. First, the degree to which inter-industry trade patterns are affected by closer economic integration, holding other influences constant. As noted in an earlier section, changes in inter-industry trade patterns in Canada and other developed countries have not been a notable outcome of trade liberalization. Second, the degree to which existing industrial clusters are characterized by economies or diseconomies of scale.

With respect to the second potential link, firms that can better adapt to and exploit an environment of freer trade should expand relative to those that, for one reason or another, cannot or do not quickly and readily adapt to the new environment. The ability and willingness to adapt to new opportunities and threats in the economic environment will depend upon a host of organizational factors, including the capabilities of managers and other employees, access to financial capital and other resources, and the physical location of the firm. Location itself may help a firm acquire resources that are critical to responding to the changed economic environment. For example, being located in a centre-of-excellence for a particular activity should enable firms to better exploit the external economies generated within that centre. However, firms located in less economically favourable regions, perhaps originally to take advantage of government grants, should find themselves relatively disadvantaged given the increased competition associated with closer economic integration.

To the extent that certain types of organizations in an industry make a particularly strong contribution to the growth of industrial clusters, economic integration might alter the formation and growth of economic clusters by strengthening or weakening the competitive position of these organizations. As shall be discussed below, there is no consistent evidence that, for example, the size or ownership distribution of organizations influences the likelihood of industrial agglomeration. Rather, the strategies of individual firms seem to be more important.

In this regard, the response of Canadian-owned MNCs and large foreign-owned firms in Canada to closer economic integration (the third potential linkage) would seem to be the critical link between closer economic integration and the mix of value-added activities in a country.[23] This perspective is reinforced by numerous case studies of resource allocation decisions within MNCs that document the growing propensity of global firms to increase the level of specialization of value-adding activities based on the relative strengths and weaknesses of the different regions in which they operate.[24] To the extent that existing clusters or agglomerations of efficient and successful firms are important determinants of the attractiveness of a region for a specific value-added activity, it may, therefore, also be an important determinant of geographical specialization patterns undertaken by MNCs in response to the opportunities and threats created by closer economic integration. However, if location attributes are relatively unimportant sources of influence on the relocation of MNC activities, economic integration may neither augment nor mitigate the impact of extant industrial clusters on the location of higher value-added activities.

As noted in an earlier section, specific technology-intensive value-added activities are not randomly distributed in geographical space, but tend to cluster in some specific regions. At the same time, the location of clusters is not immutable over time. Rather, clusters expand and contract geographically, and new clusters emerge in areas that are non-contiguous to those encompassing older clusters. The limitations of the theory discussed in this section therefore focus attention on the empirical question: what factors or set of factors determine the emergence, growth and (possible) demise of regions as attractive locations for clusters of higher value-added activities?

Evidence on the Determinants of Clustering

> The short answer to such questions as what is the minimum size and population density of a region and the level of development that will confer external economies, how great are these, and at what point do diseconomies begin to outweigh the advantages of further development? is that we do not know.[25]

NOTWITHSTANDING THAT THE PRECEDING QUOTE is almost 25 years old, it still accurately summarizes the relative dearth of precise information bearing upon the optimal size and (geographical) scope of regional agglomerations of different types of economic activity. At the same time, there is a growing body of research that seeks to identify some broad characteristics of industrial clusters. In this section, an attempt is made to summarize the available evidence on a set of characteristics that have been considered important.

Size Distribution of Firms

IN MANY CONTEMPORARY DISCUSSIONS of the dynamics of innovative regional clusters, the importance of vertical disintegration and cooperation among small, flexible specialized firms is stressed as a critical feature. The discussants usually have in mind the Silicon Valley model of a high-technology region. As noted earlier, however, other models identify the stimulus to a cluster imparted by a few relatively large firms. In these so-called hub-and-spoke models, large innovative firms contribute to clustering as new firms are created as spin-offs from the hub companies and as specialized service and input providers are attracted to the region by the presence of these hub companies.

On balance, there is little consistent evidence that clustering is associated with a concentration of smaller firms, rather than the hub-and-spoke model. One possible explanation for the inconsistent research findings on the relationship between clustering and the size distribution of firms is that other factors may confound the identification of any simple relationship. For example, one might anticipate a relationship between clustering and vertical disintegration. The contracting out of value-added stages contributes to the creation and growth of specialized skills and knowledge that, in turn, foster innovation. All other things constant, smaller firms are more likely than larger firms to contract-out various stages of the value-chain. However, the size and degree of contracting out are conceptually distinct phenomena, and one would presumably want to identify separately their contributions to industrial clustering. Similarly, a larger average firm (and plant) size in a region may be associated with a larger overall scale of economic activity in the region. While the latter might reflect significant external economies of scale, larger average plant and firm sizes may not be important contributing factors. Rather, they may be statistical artefacts of the plant's (or firm's) presence in a large metropolitan area.

In studies where attempts have been made to identify separately the contribution of vertical disintegration to the clustering process, there is fairly consistent evidence of a positive relationship between vertical disintegration and clustering.[26] Vertical disintegration, in turn, appears to be related, as might be expected, to the overall scale of industrial activity. A larger overall scale of activity creates the pooling effects that sustain the presence of specialized providers of business and technical services. The latter seem to be especially important in motivating and sustaining the viability of industrial clusters.[27]

There is less consistent evidence regarding the separate relationship between clustering and the size distribution of plants and firms. For example, Kim, Barkley and Henry (2000) find that industries with larger average establishment sizes exhibit greater spatial concentrations of establishments in nonmetropolitan areas. Conversely, Enright (1994) finds that, for state-level employment concentrations, large establishments discourage rather than attract employment.[28] Yet another study looks at clustering patterns of producers by size in a major manufacturing state of the southeast United States and concludes that progressively smaller producers do not have a greater tendency to cluster geographically, above and beyond the general tendency of industry to cluster in space.[29] Specifically, that study finds that clustering increases up to some size threshold and then starts to decrease.

In summary, the available evidence suggests that the presence of a critical pool of specialized business and technical services promotes vertical disintegration which, in turn, encourages and sustains clustering. However, the size distribution of firms in a region does not seem to have a uniquely identifiable impact on incentives to cluster. Obviously, specialized business and technical services are more likely to locate in a region already characterized by a concentration of substantial economic activity. The issue confronting policymakers who are trying to foster the growth of new clusters in competition with existing clusters is how to attract the requisite specialized services to promote and sustain industrial clustering. As Krugman (1991) notes, relocation of clusters can emerge spontaneously if expectations become widespread that a relatively undeveloped region is becoming more attractive as a location for industrial activity than other developed regions. This perspective naturally leads to the quest for the Holy Grail of regional developers — the determinants of location advantage. Evidence on those determinants will be considered below.

At this point, one preliminary policy implication might be inferred. Industrial policies that seek to encourage the growth of small and medium-sized enterprises relative to large firms, or the reverse, are unlikely to promote industrial clustering in any systematic way. Rather, it seems more appropriate to favour policies that promote the attractiveness of a region to a broad cross-section of technology-intensive firms.

FOREIGN OWNERSHIP

IN CANADA, THE SUBSTANTIAL PRESENCE of foreign-owned establishments has long been the focus of policy debates in the context of innovation and industrial development. One long-standing view is that foreign ownership discourages innovation.

As noted above, this controversy has a parallel in the different hypotheses surrounding the linkage between foreign ownership and industrial clustering. Specifically, one hypothesis is that foreign affiliates operate as miniature replicas of their parent affiliates, and acquire the bulk of their technical expertise through transfers from their parent firms. Hence, the presence of foreign affiliates discourages the formation of a critical mass of specialized professional and technical expertise that, in turn, supports vertical disintegration and the associated agglomeration economies. According to another hypothesis, this view of foreign ownership is outdated, and foreign affiliates are increasingly dispersing value-added activities on a global basis to exploit differences in location advantage. In this context, foreign-owned establishments will be no less willing to utilize professional and technical expertise located in Canadian clusters than are Canadian-owned firms. Indeed, if MNCs have superior knowledge about international differences in location advantages for alternative value-added activities, they may be quicker than domestically owned firms to expand within Canadian clusters when the latter enjoy relevant location advantages.[30]

The balance of evidence on this issue is that foreign ownership, *per se*, is a relatively neutral influence. That is, the dynamism of a cluster in a host country depends upon other industry and country effects.[31] Moreover, systematic negative effects of outward foreign direct investment on clustering in home countries are also hard to identify. For example, Fors and Kokko (1998) describe as one of the major concerns regarding the effects of outward foreign direct investment in Sweden in recent years that foreign production will lead to the departure of attractive capital- or skill-intensive jobs.[32] They study the operations of 17 Swedish MNCs and conclude that the evidence does not provide strong support for such concerns. Similarly, Lipsey, Ramstetter and Blomstrom (2000) find only a weak relationship between affiliate production of Swedish MNCs and higher blue-collar employment at home, rather than increased supervisory or research activities at home. This finding belies the notion that outward FDI by Swedish MNCs has contributed to a substantial reallocation of capital-intensive and skill-intensive activities outside the home country.[33] The authors also find little indication that Japanese MNCs have reallocated skill-intensive segments of their home operations to foreign locations, whereas

U.S. MNCs allocate the more labour-intensive parts of their output to developing countries.

In summary, foreign-owned firms are guided by location advantages, as are domestically owned firms. It is therefore appropriate to consider evidence that bears upon the determinants of location advantage for higher value-added clusters. Such evidence is provided in an eclectic range of studies encompassing case studies of individual industries or regions and econometric studies of the productivity performance of different regions.

UNIVERSITIES AND RESEARCH INSTITUTIONS

THE EXPERIENCES OF SILICON VALLEY AND ROUTE 128 in Boston point to the importance of having excellent research universities within a region to promote industrial clustering of knowledge-intensive activities. The numerous discussions of the role played by institutions such as Stanford and MIT in the creation and growth of local clusters of microelectronics and computer firms are too well known to dwell upon. What is much less clear, however, is whether the Silicon Valley experience can be replicated in other regions and (possibly) in other industries. Statistical studies, as well as case studies of specific industries provide evidence on this issue.

Statistical Studies

There is abundant evidence documenting a positive relationship between university research and measures of a region's innovation performance, such as patents filed by local firms.[34] What is less clear is how general the relationship is across industrial activities and geographic regions.

In a study focusing on 6 two-digit industries located in 25 U.S. metropolitan areas, Bania, Eberts and Fogarty (1993) find a positive and statistically significant relationship between university research and firm births in the electrical and electronic equipment industry. However, no statistically significant relationship is identified for the other technology-intensive industry in their sample, i.e. scientific instruments.[35] Similarly, Beeson and Montgomery (1993) find mixed evidence when relating the activities of local colleges and universities to regional economic development, where the latter is measured by different labour market characteristics. For example, area employment growth rates are positively related to changes in local university R&D funding, as well as to the number of nationally rated science and engineering programs at local universities. The percentage of the workforce employed as scientists and engineers is also found to be positively related both to R&D funding and to the portion of bachelor's degrees awarded in science and engineering at local universities. At the same time, there is only weak evidence that university activities affect income levels, overall employment rates or the mix of high-technology and other industries in a region.

Varga (2000) offers a possible explanation for some of the inconsistencies among findings relating university activities to regional economic characteristics.[36] He finds that the same university R&D expenditure results in a higher level of innovative activity in large metropolitan areas than in smaller cities. The most influential factor affecting the intensity of local academic knowledge transfers is the concentration of high-technology production in a metropolitan area. Technology spillovers among private firms are influenced primarily by local business service concentrations. Varga finds that innovation activity is linked between metropolitan statistical areas located within a 75-mile distance band of each other.

Varga's evidence suggests that technological spillovers from university research are fairly local, and that technical and business service employment in a region is a strong complement to university R&D. A policy inference that might be drawn is that broad-based funding of university research spread across regions and institutions in a democratic manner is unlikely to be an efficient way to promote and sustain technology clusters. Rather, funding should be concentrated in research institutions located in metropolitan areas that possess a critical mass of technical and business expertise in the area(s) being funded. To the extent that Canadian research institutions are proximate to U.S. technology clusters, they may be especially robust generators of technology start-ups in Canada.

In summary, the available evidence from econometric studies clearly indicates that university (and related) research activities can, under the proper circumstances, contribute to the growth and maintenance of knowledge-intensive industry clusters. Therefore, there would appear to be good reason for federal and provincial government funding agencies to develop a coherent strategy to allocate funding in order to achieve more systematic clustering benefits. In this regard, the importance of having established local links in place between the university research and the business and financial communities is that much of the necessary knowledge transfer is implicit. That is, face-to-face and often informal interaction among the various stakeholders is needed to harmonize the scientific and commercial foci of university research, as well as to work out plans to coordinate the movement of technology from the laboratory to the marketplace. To be sure, scientists can make useful contributions to local efforts to commercialize technology, even if they are not integrated into the local community. For example, eminent scientists can be brought from a great distance to serve as consultants on a specialized issue, or to serve on corporate boards of directors. In effect, outsiders can be used to perform activities that can be readily codified or that are fairly generic in nature, for example helping raise money from venture capitalists.[37] An implication is that government funding of research intended to encourage knowledge-intensive clustering is probably best focused on the pre-competitive stage. Local firms confronting specific technical and commercial issues related to their own corporate ventures are often in a position to recruit such talent on a consulting basis.

Case Studies

A number of case studies of technology-oriented industries also highlight the linkages between university activities and industrial clustering. The linkages encompass both teaching and research activities carried on at universities. For example, a survey of over 350 high-technology establishments in Washington State shows that Washington's high-technology industry has been primarily locally grown. In many cases, the company's founder had a personal preference to live in the Puget Sound region and attended a local university. Other major academic-establishment relationships were access to library resources, recruitment of graduates, seminars and employee degree programs.[38]

In another study, Haug and Ness (1993) report the results of interviews conducted with 33 commercial biotechnology firms in Seattle. Again, the overwhelming majority of company founders were from university, research or commercial organizations within the state of Washington. Almost 90 percent reported that proximity to educational institutions was an important influence on their choice of location.[39] The ability to attract employees was an equally important factor.

Other Factors

A NUMBER OF OTHER FACTORS have been suggested as potential sources of contribution or barriers to the emergence and growth of knowledge-intensive industrial clusters. Several relate directly or indirectly to government policies. They include taxes and subsidies, regulation and openness to competition, and transportation and communications infrastructure. More recently, interest has focused on the role that electronic commerce might play in decentralizing economic activity.

Tax Rates and Direct and Indirect Government Grants

The available evidence on these factors is limited, largely anecdotal and, ultimately, inconclusive. For example, there is little reason to doubt that lower corporate tax rates will be preferred by firms in choosing business locations, all else constant. Moreover, highly skilled individuals will prefer to live in jurisdictions with relatively low personal tax rates, all other things constant. The relevant issue is whether equilibrium tax rates can be sustained at a higher level in a well-established cluster than in regions distant from the cluster before business migration away from the cluster occurs. And, if so, how much of a tax differential can be sustained? Similarly, given the costs and risks of individual migration, can clusters sustain higher tax rates without suffering any significant out-migration of its skilled technical and professional workers?

Ireland has been a prominent focus of attention in recent years for its efforts to attract investment by tax policy initiatives. It is well known that Ireland's rates of economic growth and employment creation in the late 1980s and through the 1990s were markedly above the European and OECD averages. One expert on the Irish economy credits a low corporate profit tax rate as having been a favourable factor.[40] Grants offered to set up in Ireland using European Union aid were focused on firms specializing in knowledge-intensive activities and were apparently used effectively. Grants and other financial advantages were available for activities such as high value-added manufacturing footloose projects. Few grants or tax breaks were given to captive sectors such as local services. Walsh (2000) also points to the willingness of the Irish government to relax its previous insistence on regional decentralization, allowing cities like Dublin, Cork and Galway to attract significant clusters of firms in certain industries.

Walsh cautions that while the low rate of corporate profit tax and the reductions in personal income tax rates were important factors in Ireland's economic performance, it would be wrong to conclude that changes in the tax system triggered the boom, especially as the corporate profit tax rate actually increased in the 1980s. He also notes that the average skill levels in the high-tech sectors are significantly but not dramatically above the average for all industries. Overall, he warns that simplistic conclusions about the contribution of tax policy to Ireland's economic boom are not warranted.

Competition

Porter (1990) offers an extended theoretical defence of openness to competition as a necessary condition for a region to emerge as a knowledge-based cluster.[41] He also discusses a number of cases studies of regions that have emerged as centres-of-excellence for specific activities, and links their emergence and growth to spirited competition among producers based in the region. The presence of sophisticated customers who are demanding quality also stimulates a climate of innovation in a region. There seems to be little reason to quarrel with Porter's positive assessment of the role of competition in stimulating the growth of knowledge-intensive clusters. Indeed, it is shared by other students of regional economic growth.[42] To be sure, the preoccupation with preserving competitive domestic markets is not uniquely motivated by a policy concern to promote knowledge-based clustering. Nevertheless, it serves as a useful reminder that policies restricting foreign ownership in certain knowledge-based activities, such as audio-video entertainment products, are likely to benefit only the incumbent domestic producers of those products, at the potential cost of truncating the growth of other organizations and groups of skilled employees.

Infrastructure

It can also be readily accepted that a satisfactory physical infrastructure of telecommunications, transportation facilities and other public utilities is necessary to attract and sustain a cluster of modern, knowledge-based businesses. However, it certainly may not be sufficient. Indeed, there are numerous examples of regional governments that invested substantial funds in developing modern local telecommunications facilities with little success in attracting businesses that rely upon such facilities as an important input. In other cases, businesses did seem to respond to improvements in the local communications infrastructure, although other factors may also have been at work. Again, the point is that the attractiveness of locations for knowledge-intensive activities is a function of various factors that may well be interactive. Unless all are present to some degree, a region will fail to attract (or retain) knowledge-based activities.

Electronic Commerce

There has been substantial speculation about whether and how the emergence of electronic commerce will affect the economics of regional clusters of knowledge-intensive activities. The conventional wisdom might be characterized as stating that physical proximity between market participants will become less important in virtually every economic activity. This is largely because search costs and related transaction costs that are a function of distance should decline with the use of the Internet. Some observers have gone as far as saying that distance will become an irrelevant determinant of the location of economic activity.

In fact, search costs are only one component of transaction costs, and possibly a modest one for many types of goods and services. For example, the quality of many goods and services might be confidently asserted only after they have been used. In such cases, reduced costs of search achievable by using the Internet may be largely immaterial. In other cases, the information to be communicated may be sufficiently uncodifiable that face-to-face communication is necessary for effective information transfer.

In effect, it can be hypothesized that reductions in search costs will mitigate the importance of clustering in several ways. For example, it might expand the effective geographical radius over which technology spillovers occur by reducing local information impactedness. It might also reduce the advantages of labour market clustering by reducing excess supply and demand conditions through improved information about those conditions in different geographical markets. That is, the Internet might effectively integrate hitherto segmented labour markets. It might also make it easier and less costly for producers located outside of clusters to identify and purchase the services of specialized inputs outside their local labour markets.

Of course, it is also possible to speculate that the primary effect of electronic commerce will be to make it easier for final consumers to identify and purchase the products of knowledge-intensive clusters, thereby increasing the demand for the output of existing clusters. If external economies of scale extend beyond the current sizes of clusters, the electronic commerce phenomenon would, if anything, contribute to an even greater geographical concentration of knowledge-intensive production. The net impact of electronic commerce might well vary depending upon the specific activity in question.

POLICY IMPLICATIONS

THE AVAILABLE EMPIRICAL LITERATURE POINTS to several relatively uncontroversial directions for public policy. One is to promote and maintain competition in knowledge-intensive sectors. This effort implies policies that allow increased economic integration, including foreign investment in all sectors of the economy. Openness to foreign competition should provide policymakers in small open economies greater opportunity to allow firms in local clusters to engage in alliances and joint ventures. Collaboration among firms in knowledge-intensive sectors is a common phenomenon.[43] Indeed, it is becoming more common with the formation of purchasing and selling groups engaged in electronic commerce. A future challenge facing competition policy authorities is to ensure that achieving the private economic benefits of collaboration does not entail greater social costs arising from substantial reductions in effective rivalry. Ensuring that entry into industries such as telecommunications, broadcasting, finance, health care and other knowledge-intensive activities is relatively free of regulatory barriers should be the starting point for any coordinated set of government policies aimed at making Canadian regions attractive as locations for knowledge-intensive clusters.

A second relatively uncontroversial inference is that government policies should promote labour mobility, especially for skilled professional and technical workers. One instrument available to the government is immigration policy. While the considerations surrounding immigration policy are, of course, broader than economic concerns, increasing immigration quotas for skilled technical and professional workers is arguably the most robust tool available to policymakers to deepen Canadian labour markets with the types of workers that attract knowledge-intensive firms. However, policymakers should also be willing to tolerate a concentration of immigration in Canada's major urban areas if one goal of immigration policy is to promote industrial clusters.

A more controversial issue is the emigration of skilled and highly educated Canadians. The growing number of Canadians relocating to the United States, particularly under the NAFTA temporary visa arrangement, has raised concerns about a new Canadian *brain drain* that, in turn, is making Canada a less desirable location for technology-intensive businesses.[44] Suggestions have been made to implement policies to discourage such emigration. An example would be to require Canadians who acquired technical or professional higher education in Canada to post bonds to cover the cost of their education to taxpayers. Those bonds would be forfeited if they left Canada before some fixed period of time. In fact, we know too little about the effects of emigration on the Canadian economy. For example, it is clear that a substantial percentage of young Canadians migrate to gain work experience and additional training at leading scientific and technical organizations in the United States. If many of those Canadians return to Canada, it is very likely that there will be net gains for the Canadian economy, as these persons will increase the overall technical and professional skill level of the local workforce — a fundamental condition supporting the growth of knowledge-industry clusters. Even those who do not return might make a unique contribution to Canada's attractiveness as a location for *modern economy* activity by promoting closer technical and business ties between American and Canadian organizations. Until we know more about the long-run economic effects of temporary emigration on the Canadian economy, it is arguably premature to implement policies designed to discourage emigration.

Relatively high marginal personal income tax rates have also been identified as an incentive for highly skilled professionals to leave Canada. There is certainly a basis for concern that high personal income taxes in Canada relative to the United States have induced some (unknown) number of highly educated Canadians to migrate to the United States.[45] A problem is that the relatively greater level of publicly provided services and amenities that are largely funded by tax revenues are an attraction, at the margin, for *modern economy* workers. While it is quite possible that Canada has gotten the balance wrong from the standpoint of encouraging more rapid growth of a highly educated professional and technical workforce, it is very difficult to identify the optimal tax and expenditure levels required to encourage industrial clustering. Moreover, tax and expenditure policies are guided by a host of other considerations as well.

Even if it is difficult to be unequivocal about whether and to what extent lower marginal tax rates would encourage more industrial clustering in Canada, it does seem fair to argue that tax breaks, or direct and indirect subsidies, targeted at specific firms are inefficient. As discussed earlier, dense networks of small and medium-sized firms characterize many knowledge-intensive industrial clusters. Tax breaks and subsidies that make a region more attractive to a variety of technology-intensive companies are more likely to encourage clustering than similar fiscal policies directed at a few firms, especially if the latter are relatively large, multi-location enterprises. In that case, it seems unlikely that the beneficiary companies will become the locus of an industrial cluster, particularly if these firms were disinclined to expand in Canada absent the subsidy.

Financial support to universities and other institutions carrying out pre-competitive research is clearly an appropriate instrument to encourage industrial clustering. The goal of such support is to create an infrastructure of scientists, engineers, business experts and operating companies integrated into a unique local network of specialized expertise. The focus of network specialization should presumably be related to a broader set of location advantages. As an obvious example, knowledge-intensive clusters of organizations focusing on marine-engineering applications are more likely to thrive on the East or West Coast where large and knowledgeable users of a cluster's output exist. Less obvious, it may be ineffective for a small, open economy to encourage more than one cluster to develop in specific industrial sectors. Geographical concentration can magnify the power of competition and peer group pressure, creating incentives that encourage efficiency and progressiveness. It can also make it easier for firms (and public policymakers) to solve problems associated with the provision of the kinds of public goods required by firms to develop and maintain competitive advantages.[46]

Summary and Conclusion

This paper provides an overview of the phenomenon of industrial clustering. The motivation for this focus is the growing perception among regional geographers and economists that economic activity in knowledge-intensive sectors is characterized by regional clustering. Thus, if it is a goal of Canadian policymakers to promote and sustain the growth of knowledge-intensive economic activity in Canada, there is reason to focus on the clustering phenomenon. In particular, there is reason to focus on what makes particular locations attractive as nodes of industrial clustering.

In cases where the advantage of a location is largely based on a site-specific natural resource, the issue is relatively uninteresting from a policy perspective. However, knowledge-intensive activities draw more heavily upon human capital than physical and social infrastructure that, at least in principle, can be created anywhere. The challenge for a small open economy is to create attractive opportunities for industrial clusters in competition with larger economies that have an inherent size advantage in this regard.

The literature identifies a set of factors contributing to the external economies of scale that ultimately underlie industrial clusters. The relevant material emphasizes a distinction between *industrial policy* and policies to promote cluster formation and upgrading. For example, Porter (1998b) associates industrial policy with governments targeting their initiatives on desirable industries or national champions. The encouragement of clusters focuses on promoting conditions within regions that contribute to the realization of external economies.[47] Relevant conditions include an educated workforce, modern and efficient physical infrastructure and workable competition. Porter (1998b) and others also emphasize the importance of collaboration between governments and the private sector to build on the foundations of existing location advantages in order to create specialized niches of expertise, rather than trying to out-compete well-established rival locations. This seems particularly appropriate advice for Canada as it becomes increasingly integrated with the U.S. economy.

The basis for regionally specialized niches of expertise will likely reside in identifiable seeds of existing clusters. In any case, it would be a mistake for governments to try to pre-determine what specific location clusters should be promoted. Nevertheless, governments may need to be involved in rationalizing the competing claims of regions for public support. For example, both British Columbia and the Maritime provinces might have legitimate *a priori* claims to cultivating a successful cluster involved in the design, development and production of technology to serve the aquaculture industry. That is, they both are likely to have the seeds of a commercial cluster in the form of specialized human capital, specialized programs in colleges and universities, relevant business expertise and physical infrastructure that are complementary inputs to these activities. However, the full exploitation of agglomeration economies may only support the existence of a single cluster. Presumably, market forces would eventually provide appropriate signals as to which location is preferable. Yet, competition between provinces to tilt market support in favour of one or the other region could lead to much wasteful expenditure and even to the emergence of two unsustainable clusters.

Ideally, regional governments would avoid wasteful competition to attract and sustain industrial clusters. In practice, policy in this area might be characterized by a *prisoner's dilemma* game in which the dominant strategy of provincial government participants is to compete rather than cooperate. Cooperation here would mean allowing and encouraging patterns of regional specialization that maximize the nation's welfare rather than the welfare of one province at the expense of another. In this context, perhaps the greatest practical challenge facing the federal government is to use its financial (and moral) leverage with the provinces in order to discourage wasteful competition to cultivate industrial clusters. It would take us too far afield to speculate on how the federal government might pursue this role. However, an example might suffice as an illustration. Federal funds used to support the recruitment and retention of outstanding scientific and engineering teaching staff in Canadian colleges and universities might be assigned to the faculty member rather than to the university. Thus, the individual recipient would, in principle, be free to use the funds to work in the Canadian university that is most complementary to his or her human capital.

In other circumstances, individual regions may have sufficiently advanced clusters in specialized areas that wasteful competition among provinces is an unlikely event. In this case, the federal government might justifiably see its role as helping provincial governments enhance the specific environment of regional clusters in policy areas where the federal government plays a dominant role. For example, envelopes of federal government research funding might be created and transferred to the provinces' research funding agencies for ultimate distribution to local research communities. Hence, funding for agricultural technology might form an envelope administered by the Prairie provincial governments.

It may well be that the effective promotion of knowledge-intensive clusters in Canada requires a substantial reorganization of governmental responsibilities and financing arrangements. This could (and, perhaps, should) be the subject of additional investigation. In the interim, the federal government has at its disposal several policy instruments that can potentially modify the environment within which clusters might develop and grow. They include competition policy, laws and regulations surrounding foreign investment, immigration law, federal tax legislation, and funding for research and development. A judicious application of these instruments would work to promote economical clustering across the entire (provincial) spectrum.

ENDNOTES

1 Porter (1998a).

2 This concern is especially pronounced in countries that have used import protection to encourage the establishment and growth of tariff factories. The latter may be thought of as production facilities that would not have been established absent the import protection supplied.

3 For some basic economic models of the location choices of producers in geographical space, see Krugman (1991).

4 The value chain may be thought of as the set of interrelated activities that an organization undertakes to create value for buyers. It is, in effect, the conceptual set of stages at which commercial value is added to a product, comparable to the economist's notion of value added. For a discussion of the value-chain concept, see Porter (1990).

5 For a summary of evidence and some original empirical results, see Globerman and Dean (1990).

6 See Reguly (2000).

7 This is also an expressed concern of small open economies in Europe, such as Sweden, Holland and Belgium. Indeed, it would be fair to characterize it as a major policy focus of most European governments. See Cheshire (1995).
8 For evidence on this point, see Henderson, Kuncoro and Turner (1995). See, also, Florida (1995).
9 See Duffield and Munday (2000).
10 Quotation taken from Becker (2000).
11 Taken from Bernat, Jr. (1999).
12 See Krugman (1991. For example, he describes how the concentrated location of the carpet-making industry in Georgia was largely the result of innovations in tufting made by an early resident of Dalton, Georgia. By implication, had that individual been living in another state, the concentrated location of the industry may have evolved elsewhere.
13 Such conditions usually include intense competition and flexible labour market practices. See, for example, Pinch and Henry (1999).
14 These sources are discussed in great detail in Krugman (1991).
15 For an assessment of this assertion within the context of the software industry, see Kogut and Turcanu (2000).
16 It is also undoubtedly true that certain amenities are positively related to the size of a cluster, at least over some range of clustering. These might include the local availability of cultural activities, professional sports events and specialized medical and other services.
17 These two broad models of clustering are discussed in Gray, Golob and Markusen (1999).
18 These two alternative models of the linkage between MNCs and agglomeration are discussed in Birkinshaw and Hood (2000).
19 Some of the relevant findings will be discussed in a later section of the report.
20 This policy concern is identified and evaluated in Globerman (forthcoming).
21 This is the basic notion underlying a recent Canadian study. See Feinberg, Keane and Bognanno (1998).
22 There is no need for all firms to respond in exactly the same way or to the same extent.
23 In their empirical study, Feinberg, Keane and Bognanno (1998) conclude that unobserved differences across firms within industries explain most of the variance in MNCs' responses to changes in tariff levels.
24 For a review of recent literature, see Birkinshaw (2000).
25 Keeble (1976).
26 See, for example, Holmes (1999), and Kim, Barkley and Henry (2000).
27 See Kim, Barkley and Henry (2000).
28 See Enright (1994).
29 See Sweeney and Feser (1998).
30 In a similar vein, the presence of MNCs in a region might be taken as a signal by other investors that the region does enjoy significant location advantages.
31 See, for example, Birkinshaw and Hood (2000), and Paelinck and Polese (1999).
32 Fors and Kokko (1998).
33 Lipsey, Ramstetter and Blomstrom (2000).

34 For a review of the literature, see Beeson and Montgomery (1993).
35 See Bania, Eberts and Fogarty (1993). The authors suggest that university research is probably more important for product than for process R&D as a possible explanation for their findings.
36 Varga (2000).
37 For evidence on this latter point, see Audretsch and Stephan (1996).
38 See Haug (1995).
39 Haug and Ness (1993). This result is similar to findings from other studies of U.S. biotechnology firms.
40 Walsh (2000). Walsh also cites a ready supply of well-educated labour and easy shipping and cultural proximity to the United States as other factors.
41 Porter (1990).
42 See, for example, Asheim and Dunford (1997).
43 For discussions of the collaboration phenomenon, see Sharp (1987, and Teece (1992).
44 The CEO of Nortel Networks Corp., among others, has publicly voiced this concern. See Surtees (1999).
45 See Globerman (forthcoming).
46 This point is emphasized in Geroski (1992).
47 See Porter (1998b).

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21

Innovation in a Knowledge-based Economy – The Role of Government

INTRODUCTION

THROUGH ITS DIRECT EXPENDITURES AND TAX SUPPORT, the federal government is the country's largest investor in science and technology. In 1996/97, federal support for scientific and technological activity was over $7 billion, with just over a fifth of this amount consisting of investment tax credits for Scientific Research and Experimental Development (SR&ED). These expenditures and federal legislation to support science and technology, in particular Canada's intellectual property laws, are based on three considerations: first, that technological progress makes an important contribution to the economic well-being of Canadians; second, that, left to their own, markets will not lead to the adequate development and adoption of new technology; and third, that government intervention can help correct or compensate for market failures and improve the innovative capacity of the economy.

This paper reviews these considerations in the context of recent global developments and new understandings about the nature of the innovative process. Globalization and the shift towards knowledge-based activities underscore the importance of innovation to the country's long-term economic prosperity. At the same time, there is increasing recognition that innovation is a complex process and that a broad range of factors influence the innovative activities of individual organizations along with the critical technology flows between organizations and between Canada and other countries. The role of the federal government in promoting technological progress is appropriately assessed within this broad context.

In the following sections, we look at each of the three considerations that underlie the rationale for government investment in technology development and adoption. The section entitled *Technological Change, Growth and Competitiveness* focuses on the importance of technological change to growth and

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competitiveness. The next section, entitled *Private Markets for Science and Technology*, examines the failures that impair the operation of private sector markets for science and technology. Finally, in the last section, entitled *The Role of Government*, the arguments used to suggest that government has a significant role to play in correcting or compensating for market inadequacies are examined. Along with reviewing the evidence from empirical studies of past Canadian technology policies, the discussion looks at some additional insights that have emerged from broader structuralist approaches to assessing the role of government in promoting technological change.

TECHNOLOGICAL CHANGE, GROWTH AND COMPETITIVENESS

TECHNOLOGICAL CHANGE AND GROWTH

THERE HAS LONG BEEN RECOGNITION of the importance of technological change to the economic growth needed to create new employment opportunities and to provide a basis for continuing improvements in the average income of Canadians. Classical economists such as Schumpeter and Marx initially drew attention to the contribution of labour-saving innovation to long-term progress. Schumpeter highlighted the central role of the process of "creative destruction," whereby successful innovations displace inferior technologies, in economic development. In the mid-1950s, the neoclassical growth models developed by Robert Solow and others formally demonstrated the link between technological progress and long-run growth, showing that technological progress was necessary to overcome an economy's tendency to move to a steady state characterized by constant capital and output per worker. In an empirical study based on neoclassical theory, Solow found that only 12.5 percent of the long-run change in U.S. labour productivity could be attributed to increased capital per worker;[1] a broad category Solow named "technical change" was responsible for most of the increase in U.S. output per worker over the first half of the 20th century. It was generally understood that improvements in technology were a major component of "technical change", and this was supported by studies investigating the specific elements of Solow's residual. Edward Denison's growth accounting studies of the 1960s, for example, identified technological progress as a key source of an economy's economic growth.[2]

More recently, economic historians have focused on technological progress as a key variable in explaining the long-term performance of different countries. A recent study, which includes estimates back to 1820 for 21 economies and data back to 1950 for another 22 economies, concludes that "... the major engine of growth has been advancing knowledge and technical progress, which needs to be embodied in human and physical capital in order to have an impact."[3] Notwithstanding the difficulty of tracing the impact of R&D,[4] other studies, including a recent Industry Canada report focusing specifically on Canada's experience, have found evidence of the contribution of R&D capital to total factor productivity growth.[5] At the micro level, there is similar evidence from surveys of the opinions of successful Canadian SME managers.[6] By contributing to increases in productivity, investments in R&D and complementary physical capital have helped bring about significant improvements in Canadians' standards of living.

The transfer of technology occurs through market transactions and externalities that are outside the scope of markets. Scherer tracked the flow of market-mediated technology flows in the U.S. economy in 1974 and found that about a quarter of manufacturing R&D was aimed at improving the performing firm's production process.[7] Almost 20 percent of R&D went towards the development of intermediate inputs and capital goods used by other manufacturing industries, while approximately 50 percent was embodied in products sold to non-manufacturing industries. Just over 5 percent of manufacturing R&D was incorporated in end products going to consumers.

The positive externalities from new technology are central in the new growth theories, which extend earlier growth models by incorporating a theory of how technological progress occurs.[8] By taking account of the unique characteristics of knowledge and, in particular, its ability to be passed from user to user without losing its usefulness (i.e. its non-rival character), new growth theorists show why new knowledge is an especially valuable factor of production. Investments in equipment embodying new technological developments, and in education, invention, and related knowledge-enhancing activities are seen to be the key to overcoming the impact of diminishing returns that come into play as workers are equipped with more and more capital. Technological progress makes it possible to extract greater value out of limited resources and sustain the economy's growth over the long term.

Along with highlighting the importance of technological change, recent growth studies point to the crucial role of aggregate factors that facilitate the development and adoption of new technology. In cross-country studies, openness to trade and investment are found to be a key variable associated with more rapid productivity growth.[9] Trade and foreign investment facilitate the import of knowledge and technology and provide the larger markets that firms often need to take advantage of modern production technology. A country's ability to benefit from openness has been found to depend significantly on two other factors: capital investment and human capital development.[10] A high ratio of investment to GDP is important because much new knowledge is embodied in machinery and equipment; investment is thus a major vehicle through which new technology enters into the production process.[11] It has also been shown that inadequate human capital development has hampered some countries' ability to benefit from inflows of foreign technology.[12] Alternatively, countries that invest in education and skill development are better positioned to develop and adopt new technology.[13] The importance of human capital and tangible capital, their linkage to each other and their complementary relationship to the development of new technology is documented in a recent study of post-war productivity growth in G-7 nations.[14]

INNOVATION AND COMPETITIVENESS IN A GLOBAL, KNOWLEDGE-BASED ECONOMY

THE INCREASING ROLE OF KNOWLEDGE within the production process and the transformation of industrial economies into knowledge-based economies is focusing attention on innovation. In a global marketplace where "firms with more knowledge are winners," there is recognition of value contributed by those who manipulate and reconfigure information to create new knowledge.[15] As Morck and Yeung suggest, competition between firms now increasingly involves "competition to innovate first".[16] In highly competitive global markets, the returns from successful innovation are greater than in small, closed markets, but the risks faced by less innovative firms are also greater. Firms face strong pressures to come up with improved goods and services and to implement production changes that will improve productivity and reduce production costs. In knowledge-based economies, it is this capacity to translate ideas into useful products and processes that is increasingly becoming the major source of a firm's competitive advantage. Enterprises that cannot acquire and effectively utilize new knowledge are in danger of losing market share to their more innovative rivals.

The transformation underway in the global economy has, at the same time, facilitated the development and adoption of new technologies. With the growth in supply of highly educated workers, industrial economies are better positioned to assimilate information and to implement advanced technologies requiring specialized skills. Low-cost and increasingly efficient communications technologies are facilitating collaboration among researchers, and computer-aided design systems and virtual reality technologies are helping developers assess new engineering possibilities. As a consequence of the growth in world trade, strong increases in foreign direct investment and the expansion of global communication networks, information has become globalized to an unprecedented degree. Over the past decade, Internet use has increased at a rate exceeding 100 percent per year, while foreign direct investment (FDI), which has traditionally been an important vehicle for the transfer of technology, has grown at an exceptionally rapid pace.[17] Flows of information have also increased as a result of increased international collaboration; international agreements have grown as firms attempt to share the costs and risks of innovation in technology-intensive sectors such as information technology, biotechnology and new materials.

Although recent developments have increased possibilities for development and adoption of technical advances, there is, as yet, no significant evidence of an increasing globalization of technology. Despite the considerable liberalization that has occurred in recent decades, the evidence indicates that patterns of technological specialization of firms and countries have tended to remain relatively stable.[18] This reflects the difficulties of technology adoption, which requires capabilities that take considerable time to develop. Tacit knowledge that cannot be codified and that is acquired through practice is an important factor underlying the technological capabilities of innovative firms. Without developing an adequate internal base of tacit knowledge, firms are limited in their ability to implement new technologies. On the other hand, firms with strong innovative capabilities are well positioned to accumulate new knowledge and build on their past successes. This self-reinforcing process of knowledge accumulation helps explain the persistent leadership of particular firms and countries in given areas of technological development.[19] It also underscores the significant challenge confronting countries that have lagged behind in their technological performance and that aspire to improve their international standing as knowledge-based economies.

These considerations have clear relevance for Canada. A number of studies have pointed to weaknesses in this country's technological capabilities. Researchers have drawn attention to a number of troubling indicators, including:

- The low share of revenues Canadian industries devote to R&D compared to industries in other OECD countries (Table 1);
- The low number of U.S. patents received by Canadian firms;[20]
- The modest quality of Canadian patents (in the United States), as suggested by the relative infrequency of their citation in subsequent (U.S.) patent applications (Figure 1);[21]
- The limited extent to which Canadian firms exploit the public knowledge made available by the U.S. patent system;[22] and,
- The slow pace at which small and medium-sized Canadian enterprises have adopted advanced manufacturing technologies by comparison with SMEs in the United States.

TABLE 1

R&D INTENSITY BY INDUSTRY

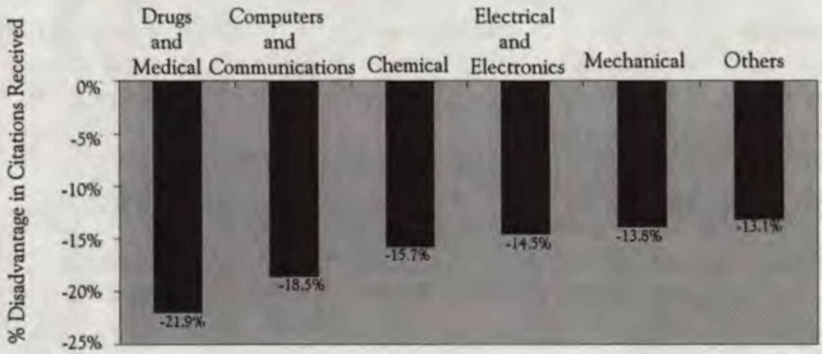
	R&D EXPENDITURE AS A PERCENTAGE OF VALUE ADDED					
	CANADA		UNITED STATES		OECD – 14	
	1988	1995	1988	1994	1988	1994
Total Manufacturing	3.0	3.3	8.9	8.0	6.6	6.6
Food, Beverages and Tobacco	0.5	0.5	1.3	1.2	1.1	1.1
Textiles, Apparel and Leather	0.7	0.9	0.5	0.6	0.5	0.7
Wood Products and Furniture	0.4	0.3	0.4	0.4	0.4	0.5
Paper, Paper Products and Printing	0.9	0.5	0.7	1.3	0.6	0.9
Chemicals	3.5	4.2	8.7	10.0	8.1	8.8
Industrial Chemicals	2.8	2.0	7.6	8.0	8.2	8.5
Pharmaceuticals	7.6	18.2	21.1	23.7	19.7	22.0
Petroleum Refining	7.6	6.2	10.6	9.3	5.4	4.2
Rubber and Plastics	0.7	0.8	2.1	3.1	2.6	2.9
Non-metallic Mineral Products	0.5	0.3	3.1	2.1	2.3	1.9
Basic Metals	1.8	1.9	1.5	1.6	2.3	2.6
Ferrous Metals	0.7	0.6	0.9	0.9	2.0	2.3
Non-ferrous Metals	2.8	3.1	2.5	2.7	3.0	3.3
Metal Prod., Machinery and Equip.	6.3	6.4	16.2	13.4	11.6	11.1
Fabricated Metals	0.7	1.3	1.3	1.3	1.3	1.3
Non-electrical Machinery	1.4	1.6	3.1	4.0	4.3	5.5
Office and Computing Equipment	24.7	22.9	55.4	49.5	30.3	29.6
Electrical Machinery	2.4	2.0	3.9	5.9	7.7	8.7
Radio, TV, Communication Equip.	30.2	32.2	24.6	15.0	19.8	17.1
Shipbuilding	0.0	0.0	0.0	0.0	2.1	2.8
Motor Vehicles	0.8	0.7	17.5	16.5	11.3	12.2
Aircraft	26.3	19.4	50.6	36.1	44.8	34.1
Other Transportation Equipment	0.5	0.1	5.2	3.8	7.2	6.0
Scientific Equipment	3.3	4.0	11.7	21.0	9.6	16.2
Other Manufacturing	3.2	3.6	2.3	3.7	1.6	2.4

Source: OECD, *Science, Technology and Industry Outlook, 1998*, Paris: OECD, 1998.

Michael Porter has attempted to compare the innovative capacity of different countries through an innovation index that combines various measures of R&D with an education indicator and two policy indicators (strength of intellectual property protection, openness to international trade and investment).[23] Canada ranked sixth among the 17 OECD countries in the sample in 1980, but had dropped to ninth in 1995.

FIGURE 1

RELATIVE IMPORTANCE OF CANADIAN VS. U.S. PATENTS BY TECHNOLOGICAL CATEGORY



Source: Trajtenberg (1999).

These indicators provide a partial and incomplete picture of the innovative activities of Canadian firms. Much technological change is the result of minor innovations that would not be labelled as R&D or show up in patent data. The potential contribution that cumulative, relatively minor technical improvements can make to productivity growth was illustrated in Hollander's classic analysis of DuPont's impressive growth over the 1929 to 1951 period.[24] More recently, Baldwin has shown that growing small and medium-sized Canadian enterprises undertake considerable innovative activity that is not considered formal R&D.[25] In a 1996 Statistics Canada survey of small new entrants, only a small percentage of firms reported that they had introduced an entirely new product or process, but many respondents indicated that they engaged in informal R&D activities, such as adapting new technologies and bundling services or quality with a good to offer a unique product.[26]

While there is a need for a more comprehensive mapping of Canada's position as a knowledge-based economy, it is unlikely that additional numbers will change the general message with respect to the formidable challenge facing Canadian firms in the new economic environment. Concerns about the innovative capacity of Canadian firms are also raised by studies showing that, on the basis of both labour productivity growth and appropriately adjusted measures of multifactor productivity growth, the performance of Canadian manufacturing firms since 1980 has lagged significantly behind that of U.S. firms.[27] The evidence suggests that Canadian firms must still undertake considerable investment to build the technological capabilities that lead to success in highly competitive global markets. It is against this background and in the context of the significant theoretical and empirical literature pointing to the importance of technological change to a country's economic well-being that we look at the role of government in supporting innovation. After looking briefly, in the next section, at deficiencies in private markets that suggest a possible role for government, we look in the following section at what available studies can tell us more specifically about the appropriate focus for government policies to promote technological change.

PRIVATE MARKETS FOR SCIENCE AND TECHNOLOGY

IT IS GENERALLY ACCEPTED THAT PRIVATE MARKETS operate inadequately in the area of R&D. Since research and development activities tend to have significant positive spillovers, they will attract inadequate investment by private firms. This market failure, which is recognized by virtually all governments, is discussed below. In a global economy, the spillover benefits of R&D partly accrue to the residents of other countries. This reduces, but does not eliminate, the need for intervention to correct the inadequate incentive for R&D by private firms.

Without questioning the traditional rationale for government support of R&D, recent studies indicate that technological change is a complex process, involving a variety of institutions and the interaction of a range of different actors. Externalities are only one of the reasons for the inadequate performance of private markets. Market failures and institutional rigidities may impede the development, acquisition and use of new knowledge at several points in the innovative process.

One of the major contributions of the recent research has been to replace the linear model, which compartmentalized innovation into basic research, applied research, development and commercialization, with a more realistic interactive model.[28] The production of a marketable good usually involves numerous incremental improvements along the way through design, testing, manufacturing and retesting. While scientific findings often stimulate new product developments, there is also a reverse flow, with market signals pointing to strategic directions for future scientific research and inventive activity. Extensive interactive and feedback effects characterize the flow of ideas and information between scientific research, product development, product testing, product design, manufacturing and marketing.

The relationships and interactive effects that characterize the innovative process have different dimensions. Some of the literature has focused on the nature of the mechanisms within organizations that lead to success in acquiring knowledge and translating it into actions that improve performance. Studies have attempted to identify the key organizational attributes and management practices of so-called "learning organizations".[29]

Another strand of literature has emphasized the key national dimensions of the innovative process. Here, the focus is on the macro variables affecting innovation (i.e. openness, investment, human capital development) and the links between various institutions, including organizations that concentrate on basic research and firms interested in applying knowledge to the creation of new products and processes. One component of this literature emphasizes the important role of a well-developed national innovation system.[30]

In a third approach, attention is given to the networks established and the interactions occurring at the regional level. Porter has been influential in promoting the idea that firms improve their innovative capacity by locating in clusters that contain related firms, suppliers and associated institutions.[31] Studies have pointed to the contribution that knowledge spillovers within a city or region and the availability of a pool of skilled labour can make to strengthening technological capabilities.[32]

From a broad perspective that incorporates these different dimensions of knowledge development, innovation will be affected if there are systemic weaknesses within organizations in the factors underlying the agglomeration of economic activities within regions and cities, or in the knowledge and communication networks created within an economy and linking a country to other industrial nations. Market failures, including imperfect information, indivisibilities, externalities and the public-good nature of knowledge, impact to some degree on market operations at each level: within organizations, regionally, nationally and internationally.

Recent studies have highlighted the particular importance of technology diffusion to the process of technological change in Canada. For example, an OECD study that looks at the contribution of technology imports in the form of machinery, equipment and components, finds that this "goods-embodied diffusion" is particularly important for smaller economies, like Canada;[33] technology imports make a much smaller contribution to the technology intensity of economies such as the United States, which has a greater R&D capacity and is much more technologically self-reliant. One study of OECD economies found that for smaller economies, total productivity growth was, in fact, more responsive to changes in the R&D of its main trading partners than to changes in domestic R&D.[34] The substantial spillover benefits Canada has received from U.S. R&D have been documented in a number of studies. One recent study, which examined eleven Canadian manufacturing industries over the period 1991 to 1996, found that R&D spillovers from the United States (primarily intra-industry spillovers) contributed to improved performance in all cases and were the major factor behind productivity growth in eight industries.[35]

The implication of these findings is that market limitations that impede the diffusion of new technology are likely to be particularly costly for the Canadian economy. The process of technology diffusion is likely to involve significant innovative activity as newly developed processes must generally be adapted and refined to meet a firm's particular needs. Hence, market failures that are of concern because of their impact on the development of new technologies are also problematic in terms of technology diffusion. If firms underinvest in worker training, for example, because they cannot fully capture the resulting benefits (another instance of an appropriability problem), this is likely to impact their capacity both to develop new technologies and to effectively adopt technologies developed by others.

However, evidence on the importance of technology diffusion also focuses the spotlight on a range of market failures that may impede the transfer of new technology. These include the information problems that beset markets for technology. With much of Canada's technology being imported, barriers affecting the operation of the major vehicles of international technology transfer, trade and foreign direct investment are also of concern.

These issues take on additional significance in so far as they impact on the application and diffusion of so-called "general purpose technologies" (GPT). The introduction of steam and electrification are examples of such major innovations with long-term and far-reaching implications for the way economic activities are performed and organized. Many observers believe that, in the current period, dramatic progress in information technology has given rise to a new general purpose technology (GPT).[36] There are inevitably long lags before GPTs are incorporated in new products and processes and their potential is fully exploited. From a policy perspective, the focus should be on ensuring such lags are not unnecessarily prolonged because of market deficiencies or a failure to appropriately adjust government policies to new market circumstances.

Against this background, a number of more significant problems impeding the operation of private markets for science and technology development and use are discussed below. Given the multifaceted and complex nature of innovation, however, an examination of the factors undermining the efficient allocation of resources towards science and technology can only cast light on some of the factors that influence the process of technological change. Market failures are important, but, as emphasized in a recent OECD report, they are only part of the story:

> Competitive markets are a necessary but not sufficient condition for stimulating innovation and deriving the benefits from knowledge accumulation at the level of firms and individuals. Firms are not "simple algorithms to optimize production functions," but learning organisations

whose efficiency depends on numerous and often country-specific institutional, infrastructural and cultural conditions regarding relationships among the science, education and business sectors, conflict resolution, accounting practices, corporate governance structures, labour relations, etc.[37]

R&D EXTERNALITIES

IN THE CASE OF R&D, the main source of market failure is the inability of individuals and firms to prevent others from making use of the new knowledge they generate. From society's point of view the resulting externalities are a positive good;[38] since knowledge doesn't lose its utility as it is used and re-used; and since it can be transmitted at close to zero cost, there are public benefits from the widespread sharing of new knowledge. From the knowledge-producing firm's perspective, however, there is less incentive to invest in R&D if the benefits cannot be fully appropriated. Due to the existence of significant externalities, some research with high social returns will not be undertaken by private investors.

Technology spillovers benefit other firms in the same industry but also firms in unrelated industries who may gain new knowledge that contributes to their own innovative activities. Very large spillovers arise from some activities, including basic scientific research, and innovation leading to the development of pathbreaking technologies, such as electricity, the internal combustion engine and the computer. The contribution of the latter "general purpose technologies" tends to become apparent only with a long lag, following a period of learning and a significant process of economic adjustment.[39]

Externalities arising from the public-good properties of knowledge contribute to a significant disparity between private and social returns to R&D. Case study and econometric evidence indicate that social returns on R&D range from 20 to 150 percent, varying significantly among industries and activities.[40] This is well above the return on high-risk investment in physical capital, and it is at least double the private rates of return on R&D investment.[41] In the presence of such large externalities, private firms, left to their own, will invest too little in R&D.

INDIVISIBILITIES AND ECONOMIES OF SCALE

IN SOME CASES, the minimum size of the R&D investment required to undertake a project exceeds the financing resources of individual firms. Collaboration may be necessary for Canadian firms to participate in large-scale project development, although this may be problematic from a competition perspective, especially for research and development that extends to the "near-market" stage. For some major scientific research undertakings, investment requirements are so great that international collaboration is called for.

Large size is a particular advantage for high-risk projects with a high variability in R&D returns. In the case of pharmaceuticals, for example, outcomes tend to be highly skewed; one study found that over half of the quasi-rents pharmaceutical companies realized from 99 new drugs introduced into the U.S. market in the 1970s, came from the ten entities.[42] Large firms are better positioned to pool such risks by undertaking a large number of projects with outcomes that are independent of each other.

One of the consequences of the indivisibilities in innovation is that market forces could lead to substantial overinvestment in certain areas of R&D. Where substantial indivisibilities exist, competition to develop new technologies can result in especially wasteful duplication of research efforts. This has been a feature of innovation surrounding some major technological breakthroughs, such as superconductivity and HDTV.[43]

The existence of significant economies of scale in innovation is a particular problem for small and medium-sized Canadian firms (SMEs). Since small new entrants that have no stake in existing products can be an important source of major new innovations,[44] this is also problematic from an economy-wide perspective. The lower returns smaller firms realize on their investment in R&D has been recognized by the market. For example, Mork and Yeung find that financial markets attribute greater value to the increased R&D spending of larger firms.[45] Small firms that develop significant innovations often enter into licensing arrangements with larger corporations to gain access to the commercialization resources and large markets needed to justify product development. Canadian biotechnology firms, for example, generally sell their research findings to multinational pharmaceutical companies for a royalty that is well below that which could be earned from completion of Phase III clinical trials.[46] In general, the existence of research economies gives additional significance to evidence pointing to the limited outward orientation of Canadian SMEs.[47] They also focus attention on various trade impediments faced by SMEs and on transactions costs that have impeded the development of consortia through which smaller enterprises could share the costs and risks of investing in export market development.

Imperfect Information

IMPERFECT INFORMATION IS ENDEMIC in markets for science and technology. Both the financing of R&D and the diffusion of new technologies are affected by information asymmetries and deficiencies.

In terms of R&D financing, problems may arise because of information asymmetries that occur where borrowers are much better informed about the risk characteristics of projects than lenders.[48] With information asymmetries, there is a tendency for interest rates to rise and for all but the most risky projects to be pushed out of the loan market. It has been shown that, in this situation, the result may be that interest rates are incapable of balancing loan supply and demand and nonprice rationing is necessary. This will impact most heavily on SMEs that have less tangible assets that can be pledged as collateral. SMEs will also be disadvantaged relative to large firms because of their poorer access to alternative sources of financing, including internal funds and equity capital.

With respect to the diffusion of technology, the fundamental problem, as Kenneth Arrow noted many years ago, is that "its value to the purchaser is not known until he has the information, but then he has in effect acquired it without a cost."[49] This problem may arise even when owners have acquired recognized property rights over newly created technology. Without intellectual property (IP) rights, however, it is not possible to have markets for the licensing of technology.

Other Problems Affecting the Diffusion of Technology

THE DIFFUSION OF NEW TECHNOLOGY may be subject to other market failures.[50] One way in which information about new technology diffuses is through observation; firms that are late adopters observe and learn from the experience of early adopters. This gives rise to an externality that may impede the diffusion process in the same way that externalities impair the R&D process. Early adopters who cannot fully appropriate the benefits of their expenses on adoption may invest less than they otherwise would in identifying and evaluating new technologies. As a consequence, new technologies may diffuse at a slower than ideal rate.

However, there is also the danger of an opposite tendency in situations where adopters receive their information on new technology primarily from the advertising and promotional activities of capital goods suppliers. In competitive markets where firms are promoting their own brands, rather than technology in general, advertising will tend to be oversupplied. This will have the effect of encouraging firms to adopt new technologies earlier than may be optimal from society's perspective.[51]

The Role of Government

AMONG BOTH ECONOMISTS AND POLICYMAKERS, there has long been support for the view that governments have a role to play in responding to deficiencies in private markets for science and technology. While not questioning the need for intervention, recent contributions by economists who view technological change in an institutional or evolutionary context have emphasized the complexity of the issues in this area and the difficulties of defining a precise role for government. This view was initially expressed by Nelson and Winter in the early 1980s:

> The anatomy of market failure is focused on equilibrium conditions of stylized market systems ... [whereas] such a discussion should properly focus on problems of dealing with and adjusting to change. It involves in the first instance abandonment of the traditional normative goal of trying to define an *optimum* and the institutional structure that will achieve it, and an acceptance of the more modest objectives of identifying problems and possible improvements. In part it represents a more general acknowledgement that notions like market failure cannot carry policy analysis very far, because market failure is ubiquitous.[52]

Notwithstanding the uncertainties that arise where there is a lack of clear normative standard on which to base policy, recent studies and reports support certain general observations. First, although it "cannot carry policy analysis very far," the notion of market failure still provides a useful starting point for the development of technology policies. Government intervention to correct market failures, of course, has its own costs. Moreover, policymakers, like other market participants, must operate within an environment of imperfect information. In some situations, information gaps will seriously limit the development and effective implementation of government policies. Still, where there are major market failures, as in the case of R&D, there is considerable scope for the implementation of policies that can significantly improve market outcomes.

Second, the role of government is appropriately viewed in a broad context that gives recognition to the complexity of the innovation process and the many ways in which government necessarily impacts on technological change. Even if it did not invest in science and technology, the federal government would still be a key player within the national innovation system because of its important influence over various economic and institutional factors that determine the economy's capacity to develop and adapt new technology. It is important to formulate an overall approach to science and technology development that takes explicit account of the significance of various government actions. Policymakers are challenged to use their considerable influence both over the key macroeconomic variables (i.e. openness, capital investment) and over important organizational and institutional factors to create an environment that is favourable to technological change.

Third, in the emerging global economy, the appropriate role of government is increasingly conditioned by international developments. As noted above, although there are large international spillovers from R&D, the externality argument that justifies government support for R&D only applies to spillover benefits that occur within Canada. While this might suggest that government should target its support towards activities with substantial *domestic* spillovers, this would be difficult to effectively implement in practice. Moreover, government support for R&D gives rise to other benefits. It improves the capacity of Canadian firms to adopt new technology, and to take advantage of the spillovers from foreign R&D. It also improves Canada's ability to attract certain research-intensive activities that are likely to bring important social benefits in the form of new knowledge and new skills — benefits that might "spill over" to Canada if these activities were instead located in the United States, but only with a considerable lag.

Another consequence of global developments is that Canada is obligated to ensure its support for science and technology adheres to new international rules of the game — in those sectors where international rules do indeed prevail. The 1991 Uruguay Round Agreement on Trade Related Intellectual Property Rights (TRIPs) marked a significant achievement in efforts to move towards international harmonization of intellectual property regimes. More recently, as a result of the WTO "Agreement on Subsidies and Countervailing Measures," signed in Marrakech in 1994, limits have been established to control the degree to which governments can support industrial and pre-competitive research. Countries that exceed the prescribed limits may be subject to disciplinary action.[53]

Since Canadian governments already implement a range of policies to respond to deficiencies in private markets, the relevant question is whether current policies are appropriately supporting the development of innovative, competitive Canadian enterprises. Does Canada's poor performance in formal R&D reflect inadequacies in government efforts to correct or compensate for problems besetting markets for science and technology? Do Canadian policies reflect new understandings of the nature of the innovative process and take adequate account of the costs of government intervention? Is there a need to modify existing policies in light of the increasing importance of knowledge-based activities or of the new constraints associated with increasing globalization?

We attempt to shed light on these issues by examining government efforts to promote R&D, and to help build an innovation system in which strong links between various institutions and agents facilitate the development and adoption of technology. The important influence of other more general government policies, which help shape the overall environment for technological change, is also briefly considered.

PROMOTING R&D

ALL GOVERNMENTS RECOGNIZE THE NEED to encourage R&D, and do so through the protection of intellectual property rights and a mix of supportive measures that generally include tax incentives, subsidies, and government procurement of advanced technologies. Most governments also directly undertake significant R&D within government departments and public agencies.

Intellectual Property Laws

Intellectual property laws attempt to remedy the market failure in R&D markets by granting property rights that recognize the inventors' exclusive right to make, use or sell an invention. Under Canadian law, for example, inventors can apply for a patent that will provide up to 20 years of protection for inventions that meet the tests of novelty, utility and ingenuity. Patents and other intellectual property rights increase the extent to which the benefits of innovation can be appropriated and thus help restore the incentives within the system for private firms to undertake R&D. Intellectual property rights cannot be secured for some types of innovation, however — including some important innovations in soft technologies such as organizational and management practices — and they do not have the same importance for all sectors. In one U.S. survey, patent protection was judged to be essential for 30 percent or more of the inventions in only the pharmaceutical and chemical industries.[54] In three other industries (petroleum, machinery, and fabricated metal products), patent protection was considered to have been essential for the introduction of only 10 to 20 percent of inventions. In a more recent study of 19 European industries, the sales-weighted patent rate for new innovations was found to average 36 percent for product innovations and 25 percent for process innovations, again varying widely between industries.[55]

Complex issues are involved in the design of intellectual property laws that appropriately balance the gains in dynamic efficiency from increased innovation against the losses in static inefficiency from underproduction of the goods subject to IP protection. In the case of patents, for example, there is continued debate on what is ideal in terms of patent duration, patent breadth or scope, and the provision of compulsory licences. Besides limiting access to patented goods, strong patent protection could reduce the diffusion of knowledge that is a stimulus and building block for follow-up innovations. Some recent studies argue that, since innovation now depends largely on the exploitation of existing knowledge, the emphasis should be on promoting the dissemination of new findings so that they can be combined with other information to create new products and processes. This model calls for a system that encourages firms to seek patents, which are preferable to trade secrets in terms of information disclosure, but that reduces the stringency of patent protection and provisions governing their use, such as compulsory licensing, to promote knowledge diffusion.[56]

The optimal features of an IP regime will differ if viewed from the perspective of a country, such as Canada, that is a relatively small contributor to the world technology pool, rather than from a world or U.S. perspective. As a technology user, Canada continues to face risks from too weak intellectual property rights that might hamper development of the innovative capabilities needed to imitate and adapt foreign-produced technologies. As McFetridge points out, these risks appear to be greater for Canada than for a country such as Korea that has become highly proficient at reverse engineering and is able to acquire advanced technologies at relatively low cost.[57] Still, the patent system that enhances Canadian welfare will tend to be less stringent than the optimal world standard.

Analyses of optimal IP systems are largely academic, given Canada's international commitments under NAFTA and the TRIPs Agreement. However, available evidence does not suggest that the incentives to innovate provided by the current intellectual property regime are inadequate.[58] The more significant current concern would appear to be coming from international pressures to extend IP laws or develop new *sui generis* protection to respond to challenges posed by the growth of digital content. In a recent paper, Cockburn and Chwelos point out that proposed U.S. and EU legislation to protect proprietary rights in databases would abandon the general principle of copyright law that facts, *per se*, are not copyrightable.[59] Proposed U.S. legislation would also curtail "fair use" access under copyright, which has been important to educational institutions. Since software piracy is already illegal in most countries and firms are developing increasingly effective technological protections, the need for new legal mechanisms is not evident. There is a danger, however, that current pressures could lead to overly restrictive intellectual property laws that impede information flows and negatively impact on the innovation process.

Tax Incentives

As noted above, IP protection does not serve the needs of all industries. Moreover, the creation of intellectual property rights is inappropriate where there is a strong public interest in the wide distribution of the results of inventive activity. A patent which reduced accessibility to a major discovery such as the polio vaccine, for example, would have great social costs. Similarly, it is in the public interest to have basic research results, with potentially far-reaching implications for various aspects of human well-being, freely distributed. The welfare costs of creating a limited monopoly through intellectual property rights are also high in the case of basic technology or generic research — such as the principles of chemical engineering, the insights behind the design of computer interfaces and the fundamentals of program design.[60] Romer and Nelson have warned of the danger of extending intellectual property rights to broad claims that encompass such basic concepts.[61]

Since intellectual property regimes are only a very partial solution to appropriability problems, there is a need for other mechanisms that will compensate for

R&D spillovers and increase the incentive for innovative activity. Tax incentives attempt to promote innovative activity by reducing the effective cost of research activities. Although R&D is an investment intended to generate future returns, Canadian companies are allowed to write off both current and capital expenditures on R&D as current expenses. In addition, under the current federal Scientific Research and Experimental Development (SR&ED) incentive, firms can receive a tax credit of 20 percent of eligible spending, or 35 percent in the case of qualified small businesses. The amount of SR&ED tax credits earned in 1995 is estimated at $1.6 billion. The important issues are whether tax incentives do, in fact, lead to additional R&D spending, and whether the social benefits from this induced R&D exceed the social costs of financing and administering the tax incentive.

On the first question, a recent review of the evidence from various studies in different countries reveals that the response to a tax credit tends to be fairly small initially, but increases over time. Available evidence, mainly from econometric studies, suggests that a dollar in tax credit stimulates about a dollar of additional R&D spending.[62] While there have been no overall evaluations of the social costs and benefits of the Canadian system of tax credits, on the basis of applicable research undertaken by the Australian Bureau of Industry Economics, McFetridge concludes that Canada's tax incentives "are likely socially beneficial."[63]

With tax incentives as with intellectual property laws, it is difficult to make the case that Canada is providing inadequate encouragement for innovation. Taking account of the SR&ED credit and provincial tax incentives, Canada's support for R&D is substantially greater than that of all other countries, including Australia, the United States and France, countries that are also known for their favourable treatment of R&D. This is illustrated in Tables 2 and 3 using the B-index, a measure of the present value of the before-tax income a firm needs to generate to cover the cost of an R&D investment and pay applicable income taxes. Canada's favourable tax treatment of R&D can be seen in its low B-index relative to other countries in both the small and large firm categories. It is not at all clear that Canada is better off by having a more generous system of R&D subsidies than other countries. Indeed some concerns have be raised that Canada's generous incentives have contributed to some poor R&D investment decisions by Canadian firms.[64] Moreover, since Canada's favourable tax treatment of R&D contrasts sharply with its high corporate and personal tax rates compared to the United States and other industrial countries, it is reasonable to expect that gains may be achieved from a rebalancing of tax incentives.

TABLE 2

COMPARISON OF COUNTRY TAX INCENTIVES FOR A LARGE MANUFACTURING FIRM, 1998

COUNTRY	B-INDEX	ATC
Canada–Quebec	0.699	0.482
Canada–Ontario	0.787	0.507
United States–California	0.879	0.521
Australia	0.890	0.570
France	0.914	0.533
Korea	0.918	0.635
Mexico	0.969	0.640
United Kingdom	1.000	0.690
Japan	1.010	0.525
Sweden	1.015	0.731
Italy	1.027	0.647
Germany	1.051	0.456

B-Index : ATC/(1-corporate income tax rate).
ATC : After tax cost of $1 of R&D investment.
Notes: California's tax system is used for the United States.
The proportion of R&D expenditure is assumed to be 90 percent for current expenses, 5 percent for M&E and 5 percent for buildings and structures.
A discount rate of 10 percent was used in calculating present values of depreciation allowances and incremental tax incentives.
Source: Jacek Warda (1999).

TABLE 3

COMPARISON OF COUNTRY TAX INCENTIVES FOR A SMALL MANUFACTURING FIRM, 1998

COUNTRY	B-INDEX	ATC
Canada–Quebec*	0.369	0.288
Italy*	0.552	0.368
Canada–Ontario*	0.591	0.464
Korea*	0.837	0.689
United States–California	0.879	0.521
Australia	0.890	0.570
France	0.914	0.533
Japan*	0.937	0.609
Mexico	0.969	0.640
United Kingdom	1.000	0.690
Sweden	1.015	0.731
Germany	1.051	0.456

* Countries providing special R&D treatment to small firms.
Notes: See Table 2.
Source: Jacek Warda (1999).

The recent *Technical Committee Report on Business Taxation* adopts this position, arguing that the gains from a lower corporate tax rate that encouraged investment in new technologies would more than offset the losses from somewhat lower incentives for the development of new technologies.[65]

Subsidies

Subsidies are an alternative mechanism to strengthen incentives for R&D — albeit a somewhat restricted mechanism, as a consequence of the 1994 WTO Agreement limiting government support for all research other than basic research undertaken by universities or research institutes. Basic research tends to generate large social benefits and to be a significant contributor to productivity growth.[66] It is significant that, in contrast to its overall R&D spending, Canada's investment in university research as a share of GDP is comparable to that of other OECD countries. Public support is important in supplementing the incentives built into a system (i.e. the system of open science) offering substantial rewards to those who first come upon and disclose significant new findings, but there are difficult questions — questions that are beyond the scope of this paper — about the appropriate amount and allocation of such public support.

As an instrument to encourage R&D by business, the advantage of subsidies is that, unlike tax credits which are available to all firms, they can be targeted towards valuable innovative projects with large social benefits that receive too little attention because of their spillovers. Policymakers may have difficulty identifying such projects, however, and they may be subject to pressures that make the successful implementation of a subsidy program difficult.

In a recent study, Lipsey and Carlaw find that, while policymakers must be sensitive to the pitfalls associated with their use, R&D subsidies have a legitimate place as part of a package of policies aimed at raising the economy's level of technological change.[67] Their review of past subsidy policies differs from that of previous researchers who have looked primarily at whether the subsidy induces the desired increase in R&D investment (the narrow incrementality test) and at whether the government has spent no more than necessary to achieve the desired benefits (the ideal test of incrementality). Lipsey and Carlaw judge a program to be successful if it results in desired changes that would not otherwise occur in R&D or in the structural factors that influence the economy's innovative capacity. To come to a judgement about past Canadian subsidy programs, they review each program against a set of design and operational criteria that they derive from a broad review of programs around the world. This approach leads them to refute past negative assessments of the Defence Industry Productivity Program, but, like previous researchers, they judge the Industrial and Regional Development Program (IRDP) and its predecessors, the *Industrial Research and Development Incentives Act* (IRDIA), the Program for the Advancement of Industrial Technology (PAIT), and the Enterprise Development Program (EDP) to have been failures.[68]

Past experience illustrates the practical difficulties of implementing a successful subsidy program. Policymakers are likely to face strong pressures to support undeserving projects and to sustain funding after it has become evident that objectives are not being met. Two general lessons can be drawn from assessments of past programs. First, subsidy programs are not the appropriate instrument for generally promoting R&D; framework policies such as R&D tax credits are preferable for this purpose. Focused policies, in which subsidies are used to encourage specific technologies or particular types of R&D, primarily have a role where market failures are large and specific.[69] Second, if subsidy programs are employed, there should be a requirement that they adhere to stringent design and operational criteria.[70] These include the establishment of clear and realistic goals that can be translated into well-defined selection criteria and provide a basis for assessing program success. The risk of major losses can be reduced through a funding strategy that involves making many small bets rather than concentrating funding on a small number of large, highly visible projects. In addition, consideration should be given to establishing special administrative arrangements that will help insulate the program from political pressures. As in the funding of university research, the government could set program objectives and assign responsibility for the distribution of funds to an independent administrative body.[71]

Public Sector R&D

Along with supporting private sector research, the federal government devotes significant resources to developing new technologies within federal laboratories. One recent report observes that technology developed at two federal research institutions, the National Research Council and the Communications Research Centre, have alone given rise to 114 spin-off firms with about 11,600 employees and 1996 sales of around $2 billion.[72] The basic technology research undertaken by such agencies tends to involve long-term, high-risk projects with potentially high returns for society as a whole.

As in the case of other government programs, there is a need for developing clear objectives that are based on the identification of market inadequacies and that are reasonable given the resources and competencies of the department or agency. Public institutions, however, are well-suited for basic technology research, or what one recent report describes as a "need-driven, creative research on new kinds of materials, new processes or ways of exploring or measuring, and new ways of doing and making things."[73] The unique contribution Canadian government laboratories — with their strong applied research capacity — make in these areas is recognized by Canadian firms.[74] Basic technology is a "grey area" falling outside the fundamental research that primarily occupies academic institutions and also outside the commercial-oriented research that is the primary focus of firms subject to competitive pressures and increasingly compressed product development cycles. As a recent U.S. study warns, without direct government involvement, there is a danger of serious underinvestment in this critical area of innovative activity.[75]

FACILITATING THE OPERATION OF THE NATIONAL INNOVATIVE SYSTEM

THE CONCEPT OF A NATIONAL INNOVATION SYSTEM focuses attention on the interactions among firms, individuals and institutions, and how these affect the flow of information and technology within the economy. The OECD observes that, along with responding to market failures, governments need to address "systematic failures" that impede knowledge flows within innovation systems and impair the development and diffusion of technology.[76] The importance of government support for the development of the national innovation system is also a theme emerging out of the federal government's recent major review of its science and technology policy:

> In addition to [its] traditional activities, the government will increasingly emphasize a new role: that of information analyst, knowledge disseminator and network builder — critical elements in the successful evolution of the Canadian innovation system.[77]

These perspectives draw upon new understandings about the nature of the innovation process. They give recognition to the interactive nature of the innovative process, which involves the integration of elements of knowledge originating from a variety of different sources. The importance of focusing on the relationship between institutions and of promoting the efficient development of the innovation system as a whole has been emphasized in recent literature.[78] Related studies have pointed to the benefits of the widespread distribution of knowledge in terms of guiding would-be inventors towards promising avenues of exploration and reducing duplication in inventive activity.[79] It is argued that even the results of unsuccessful experiments are useful since they can guide others away from "dry holes."

Governments can promote the dissemination of fundamental research findings, which have many of the characteristics of a public good and should be widely and freely disseminated. They can help reduce the transaction costs and remove barriers, including cultural barriers, that prevent fruitful collaboration among researchers in different disciplines and sectors. As well, governments can exploit the economies from a collective approach to gathering information on and evaluating new technologies. The contribution governments can make by disseminating information that helps potential users form better expectations about the profitability of adopting new technologies is discussed in a recent paper by Boyer, Robert and Santerre.[80] Other studies suggest that better informed producers are, in turn, likely to invest more in the adoption of new technologies.[81]

Governments may significantly strengthen the operation of the innovation system through activities such as:

- The development of an infrastructure that facilitates information sharing and networking among researchers in industry, government and universities;
- The establishment of mechanisms that facilitate private and private/public cooperation in technology development and that allow firms to benefit from economies of scale and scope along with available synergies from joint R&D activities;[82]
- The creation of vehicles to promote the transfer of information on new technologies, including both the results of innovative activity that are in the public domain and information on advanced technologies that can be acquired through machinery and equipment purchases; and,
- The dissemination of information on the types of organizational arrangements and human resource and management practices that will help position firms for success in a knowledge-based economy.[83]

Policymakers have come to appreciate the need for a holistic approach that pays attention to the links among various institutions that might be considered part of the innovation system. Canada's federal science and technology policies include a number of programs that focus on strengthening the innovation system. For example:

- The Networks of Centres of Excellence (NCE) program facilitates collaboration among leading researchers in universities, industry and government and helps accelerate the commercialization of research. In 1997-98, 463 companies, more than 100 provincial and federal government departments and agencies, 44 hospitals, 61 universities and more than 200 other organizations were involved in the NCE program.
- The Canada Foundation for Innovation, a government-funded corporation, provides grants for research infrastructure in universities, colleges and teaching hospitals — e.g. for the development of national online databases that facilitate access to academic articles and their use in both teaching and research.[84]

- CANARIE Inc. promotes the development of the crucial communications infrastructure of a knowledge-based economy. This private non-profit organization, which is supported by Industry Canada, 120 members and over 500 project partners, focuses on accelerating advanced Internet development and maintaining Canada's leadership in the use of information technology.
- The National Research Council's Industrial Research Assistance Program (IRAP) provides technology advisors to help Canadian companies develop and exploit advanced technology. IRAP's network of 260 advisors provides technical advice to over 10,000 firms per year.
- The Industrial Research Fellowship Program, another component of IRAP, encourages recent Ph.D. graduates in science and engineering to gain experience in Canadian industry. It helps Canadian firms develop a research capacity and build links between businesses and universities.
- Industry Canada is an important disseminator of information on technology developments and opportunities. Its *Strategis* website includes, for example: DISTCovery, a database of more than 35,000 licensable technologies around the world; the Canadian Technology Gateway, a listing of science and technology activities and capabilities in Canada; and Trans-Forum, a technology transfer tool for universities and colleges.

The OECD has included a number of Canadian initiatives in its list of "best-practice policies and programs" to promote a knowledge-based economy.[85] The Centres of Excellence program, for example, has been singled out for establishing links between industry and science, and the IRAP Fellowship program has been cited for promoting personnel and tacit-knowledge transfers between universities and industry. The OECD points to the NRC's IRAP program and *Strategis* as examples of initiatives that promote the diffusion of technologies.

Since programs in this area focus on improving aspects of the economy's innovative capacity, it is inappropriate to assess them simply by examining their contribution to increasing R&D investment. In the case of IRAP, for example, criticisms made about the difficulty of applying a narrow incrementality test do not represent a substantive indictment.[86] Applying their broader criteria, Lipsey and Carlaw find that there is "a very strong case for regarding IRAP as a success." Among other considerations, it is significant that IRAP focused on filling an important gap — i.e. developing the tacit knowledge base of firms with weak technological capabilities; that support was spread among a number of small-scale initiatives; and that IRAP was administered by the National Research Council and its operations were removed from the political limelight.

At the same time, however, policymakers need to be sensitive to the risks associated with overly ambitious programs to promote Canada's innovation system. Part of the appeal of existing programs is that government is mainly acting as a facilitator or catalyst and public expenditures are relatively modest. With larger program expenditures, there is a danger that marginal benefits will be less than those that could alternatively be achieved by reducing tax rates. In addition, U.S. research has pointed to the potentially high costs of policies which promote collaboration between public and private sector researchers by offering firms intellectual property rights over publicly funded R&D.[87] Technological change could be adversely affected if government policies restrict access to publicly supported research results with potentially wide application.

CREATING A FAVOURABLE FRAMEWORK

WHILE THE PRIMARY FOCUS OF THIS PAPER is on technology policy, the broad approach that is proposed for understanding the innovative process draws attention to the potentially influential role of a range of other government policies. Government policies determine the openness of the economy to trade and investment and clearly have a major impact on the other major macroeconomic determinants of technological change highlighted in the second section — capital investment and human capital development. Framework policies can also have an important effect on the organizational and regional dimensions of technological change. In this abbreviated discussion of government's general influence on the development and adoption of technology, we have chosen to highlight five issues.

First, given Canada's position as a small economy highly dependent on technology developed outside the country, policies that facilitate the inflow of knowledge, including workers and capital embodying new knowledge, warrant special attention. Considerable progress has been made in the recent period to improve market access and strengthen the foreign trade and investment links that serve as important vehicles for the inflow of knowledge and technology. As a share of GDP, Canada's exports and imports and its stock of inward and outward foreign direct investment (FDI) have increased substantially over the past decade. It is not clear, however, that Canadian tax and expenditure policies give adequate importance to the contribution of technology imports. Particular concern has focused on the impact of this country's relatively high levels of taxation. In 1999, total tax revenues in Canada amounted to 41.5 percent of GDP, which was well above the ratio for the United States and Japan, Canada's other major trading partner. The personal and business tax reductions proposed in the February 2000 budget will bring Canada's tax rates more in line with that of other industrial countries, assuming these countries do not reduce their own taxes over the 5-year period during which the budget proposals are to be phased in. While federal changes will leave Canada's corporate tax rate above the OECD average,[88] some provincial tax changes, especially the corporate tax reductions announced in the recent Ontario budget, will help better position Canadian firms in relation to their major U.S. competitors. Canada's personal income tax rates remain significantly above those of the United States, however, and Canada's top marginal rate applies at an income threshold that is much lower than in most other industrial countries. Moreover, there is a risk that, with the gradual reductions in personal and corporate taxes proposed over the next five years, Canada will fall further behind countries that are moving more aggressively to encourage investment and attract skilled workers. Taxes are only one of many factors that influence the investment decisions of firms and the migration decisions of skilled workers.[89] Still, as a small economy highly dependent on technology imports, it is important to consider whether Canada would be better off by following the lead of countries that are adopting bolder reforms to achieve a combination of tax rates and public services that are attractive to international investors and highly skilled workers.

Second, the contribution of government policy to Canada's relatively low rate of machinery and equipment (M&E) investment merits attention. As a share of GDP, Canada's M&E investment has been substantially below that of the United States since the early 1980s. This gap is troubling from a technology perspective, since it is through M&E investment that most new technology becomes incorporated in the production process. The contribution of government policies to Canada's poor investment performance has been analyzed by Fortin.[90] The growth of Canada's public sector net debt, which exploded over the 1980s and the first half of the 1990s, caused an increased reliance on foreign borrowing, raising the risk premium paid by Canadian borrowers and the pressure on monetary authorities to maintain high real interest rates. Fortin observes that, in addition, to get control of Canada's deteriorating fiscal situation, the federal government had to implement sharp corrective measures that delayed the economy's recovery from the recession of the early 1990s. Studies suggest that Canada's relatively high corporate taxes have also played a role, albeit modest, in reducing machinery and equipment investment in Canada relative to the United States.[91] While governments have made progress in improving their fiscal frameworks, Canada continues to bear a high debt burden — with public debt charges at the federal level still absorbing a substantial 27 cents of every dollar of revenue in 1998/99. Continuing efforts are required to reduce the debt burden and to establish a fiscal environment that is conducive to business investment.

Third, given the central role of human capital to innovation, the adequacy of government policies to support human capital development deserve careful examination. While there are a number of different dimensions to human capital development,[92] a strong educational and training system is a core element of an infrastructure designed to satisfy the labour market needs of a knowledge-based economy. On some measures of performance — especially the proportion of the workforce with post-secondary education —, Canada's educational infrastructure surpasses that of other industrial countries, but on other measures it compares poorly. International studies indicate that over a third of Canada's workforce has poor literacy skills[93] and surveys suggest that shortages of adequately trained and educated workers have impeded the adoption of advanced technologies.[94] As well, the incidence of formal training provided by Canadian employers is low by international standards.[95]

Government support is appropriately directed to helping workers acquire general knowledge and skills that employers are reluctant to finance and that individuals may be unable to finance because of the difficulties of borrowing or selling shares in their "human capital." There are different routes by which the government could increase its support for worker training. It could directly respond to financing deficiencies by introducing a loan scheme for worker training, such as exists for post-secondary education. With a view to the projected requirement for lifelong learning, the Macdonald Commission recommended that workers be allowed to set aside tax-free funds for further education and training in a "Registered Education Savings Leave Plan." More direct government involvement in the provision of training has potential appeal in the case of economically disadvantaged workers. In the United States, evidence suggests that such training programs have been effective for adults, especially females.[96] In addition, it has been proposed that the federal government consider establishing a process of national competency testing in various technical fields.[97] National standards can help address disparities arising from the devolution of training policy to the provinces and they provide a low-cost screening mechanism that is appealing to multinational employers.

Fourth, it is important to ensure that government policies help promote the development and exploitation of the period's pre-eminent technology or GPT. Many of the policy issues discussed in previous sections are relevant to this issue. In addition to addressing technological barriers impeding the application and diffusion of information technologies, however, government must ensure that its framework policies are appropriately extended to take account of new types of activities and organizations. The federal government has addressed this issue through a number of initiatives, including the introduction in 1998 of the *Canadian Electronic Commerce Strategy*, a broad framework which includes initiatives to build trust in the digital marketplace, to clarify marketplace rules and to strengthen the information infrastructure. As part of its efforts to build public confidence in electronic transactions and help Canadians realize the benefits of new information technologies, the government has developed privacy protection and cryptography policies, and is reviewing the adequacy of consumer protection provisions in the Competition Act relating to deceptive trade practices and misleading advertising. Canada has been participating in international discussions, but much work remains to be done in the development of internationally compatible policies and co-operative implementation strategies to govern global electronic commerce.

Fifth, there is a need to examine government policies that impede the role of market forces in reallocating resources from less innovative to more innovative activities. Microeconomic studies have shown that shifts of resources from less productive to more innovative and productive firms within an industry and from less promising to more promising activities within an economy make an important contribution to economic performance.[98] In recent decades, progress has been made in eliminating government regulations and subsidies that interfere with the allocative activities of the market. The role of competitive forces has expanded, for example, in the transportation, telecommunications, energy, electric power and finance sectors. Governments have moved away from "bailing out" losing enterprises and have accepted that policies to facilitate economic adjustment are appropriately directed, not at firms, but at workers and their families. The elimination or reform of policies that reduce the flexibility and dynamism of the economy, however, remains a significant challenge.

Some regulatory controls, including agricultural marketing boards and various interprovincial trade barriers, have been difficult to dismantle. While direct regulation has been reduced, some participants in traditionally regulated sectors are still subject to non-economic directives. It has been argued, for example, that the introduction of competition into the local distribution segment of telecommunications has been undermined by the imposition of vague criteria such as "fair" and "sustainable" competition, and by nationalistic policies regarding ownership and content.[99] Questions have been raised about particular corporate governance laws and capital market regulations that may detract from efforts to create an environment conducive to the formation of innovative new enterprises and the takeover or dissolution of poorly performing firms.[100] Evidence that Canadian firms use evaluation techniques that fail to recognize the inherent value of high-risk, long-term ventures has been attributed to ownership restrictions and governance regulations that weaken the competitive pressures on Canadian managers.[101] As well, concerns have been expressed about the impact of the 20-percent limit on foreign investment holdings in RRSPs and RPPs on the growth and specialization of venture capital funds that play an important role in financing innovative new enterprises.[102] These concerns remain relevant, notwithstanding the proposals in the recent budget to raise the foreign content limit to 25 percent for 2000 and to 30 percent for 2001.

Among other issues that need to be addressed in a broad review of policies that undermine the dynamics of Canadian markets is the lack of neutrality in Canada's business tax system. The proposals made in the recent federal budget will remove the bias in the current system against service activities, which have been a major source of new jobs and include some of the main knowledge-based sectors of the economy. The budget, however, continues to treat resource firms differently from manufacturing and service firms.[103] In addition, because of various tax incentives, the effective tax rate on marginal investment still varies significantly between industries and among different types of assets.[104]

CONCLUSION

THERE HAS LONG BEEN RECOGNITION of the importance of technological change and the fact that, left to their own, markets will not lead to the optimal development and utilization of technology. All governments have implemented policies to overcome or offset failures in markets for science and technology. The recent literature underscores the importance of technological change for growth and competitiveness. In a global knowledge-based environment, the fortunes of firms and economies are significantly linked to their capacity to develop, acquire and effectively utilize new technology. Recent studies also document the extent of the failures that impede the operation of private markets for science and technology, indicating, in particular, that social returns from investment in R&D are at least double their private returns.

In dynamic economies, government policies are appropriately assessed not against a normative ideal but in terms of their ability to improve social welfare. In assessing science and technology policies, there is a need to take into account the costs of implementation and the design and administration difficulties that will, to some extent, reduce program effectiveness. Governments must also ensure that their policies adhere to recent international agreements and make sense in the context of the increasing globalization of economic activity.

Canada's experience lends support to the expectation that technology policies can play a useful role in overcoming and offsetting market weaknesses, but it also provides a warning about the dangers of overly ambitious efforts to increase technological change. In promoting business R&D, studies of Canada's experience support the wisdom of relying on general policies such as tax credits and intellectual property laws, rather than focused policies that target particular activities or technologies. Moreover, despite the low rates of R&D investment by Canadian firms, the evidence does not suggest that the R&D support currently available to business through IP laws and tax credits is inadequate. Both these measures give rise to difficult tradeoffs and recent literature has tended to emphasize the costs of stronger incentives. In the case of IP laws, particular concern focuses on the reduced access to information that could occur if governments strengthen copyright protection or develop new *sui generis* legislation in the area of digital content. In the case of tax credits, recent attention has centered on the prospects for improving the climate for technological change by reducing the imbalance between Canada's comparatively generous treatment of R&D and its relatively high overall corporate tax rates.

A second main thrust of technology policy has been aimed at strengthening Canada's innovation system. Recent government initiatives respond to the understanding that "systematic failures" that impede knowledge flows and impair the development and diffusion of technology have a high cost. It is difficult to measure the effect of policies that primarily impact on firms' technological capabilities, but studies suggest that some major Canadian programs are appropriately designed to address gaps in the innovation system. Part of the appeal of existing programs, however, is that government is mainly acting as a facilitator or catalyst and public expenditures are relatively modest. More ambitious programs entailing larger tax consequences would give rise to a more difficult balancing of costs and benefits. In addition, there is a need to ensure that policies to strengthen the innovation system do not have the effect of restricting access to publicly supported research with potentially wide application.

Through its framework policies, the government exerts a significant influence over the environment for the development and adoption of technology. For a small open economy, it is especially important that framework policies are conducive to an inflow of technology from abroad. While government initiatives over the past decade have significantly strengthened trade and investment links that are important vehicles of knowledge acquisition, government tax and expenditures policies, arguably, have not given adequate recognition to this country's dependence on foreign technology. Studies suggest that government policies over the recent period have also adversely affected technological change by contributing to Canada's comparatively low rate of machinery and equipment investment. While this country's human capital investment has been impressive in some ways, there are important gaps in Canada's education and training infrastructure that call for new government initiatives. In addition, there is a need to examine government policies that impede the role of market forces in reallocating resources from less innovative to more innovative activities. Over the past two decades, progress has been made in reducing distortionary regulations and business subsidies, but there is a wide range of further reforms that could be introduced to help Canada become a more dynamic, innovative, knowledge-based economy.

ENDNOTES

1 See Solow (1957).
2 See, for example, Denison (1962).
3 See Maddison (1994).
4 As Griliches has pointed out, estimating the productivity effects of R&D is complicated by long and variable lags, problems in measuring productivity, and the existence of many other influences on productivity results.
5 See Coe and Helpman (1993), Helpman (1997) and Bernstein (1998).
6 See Baldwin, Rafiquzzaman et Chandler (1994).
7 See Scherer (1982).
8 See, for example, Romer (1986) and Lucas (1988).
9 Among the more important empirical studies are that of Baumol, Nelson and Wolff (1994), and of Sachs and Warner (1995). A recent attempt to isolate the impact of trade is made in Frankel and Romer (1999).
10 For example, Levine and Renalt (1992).
11 See Greenwood, Hercowitz and Krusell (1997).
12 See, for example, Baumol, Nelson and Wolff (1994).
13 Supporting evidence is provided in Benhabib and Spiegel (1994).
14 See Boskin and Lau (1996).
15 See OECD (1996b).
16 See Morck and Yeung, "The Economic Underpinnings of a Knowledge-Based Economy."
17 Over 1985-94, world foreign direct investment (FDI) flows increased at an annual average rate of 14.3 percent, which was over twice the growth rate in world export volume and over three times the growth rate of world real GDP.
18 This is discussed in Orsenigo (2000).
19 Idem.
20 See Trajtenberg (1999).
23 Idem.
22 Canadians taking out patents in the United States were found to cite previous U.S. patents only about 65 percent as often as patent applicants from the United States. See Jaffe and Trajtenberg (1999).
23 See Porter and Stern (1999).
24 See Hollander (1965).
25 See Baldwin (1994).
26 See Baldwin and Gellatly (2001).
27 Problems in existing measures of multifactor productivity growth are discussed in Coulombe (2000). Adjusted measures are provided in Gu and Ho (2000).
28 An important contributor to this literature has been Nathan Rosenberg. See, for example, Rosenberg (1982).
29 See Newton and Magun (2001).
30 This topic is examined in Gibbons (1995).
31 Porter (1990).
32 For example, Glaeser et al. (1992).

33 OECD (1995).
34 Coe and Helpman (1993).
35 Bernstein (1998).
36 The issues are discussed in Helpman (1998). For a dissenting view on the role of information technologies, see Gordon (1999).
37 OECD (1999).
38 There are only social gains over the short term; over the long term, society will also bear the cost of a system that discourages private investment in R&D.
39 The special issues raised by general purpose technologies are discussed in Helpman (1998).
40 *Report of the Technical Committee on Business Taxation* (1997).
41 Based on his review of the evidence, Lester Thurow estimates the social rate of return on R&D at 66 percent, almost three times the average private rate of return of 24 percent. See Thurow (1999).
42 Grabowski and Vernon (1990).
43 OECD (1991).
44 Scherer (1992).
45 They measure the effect of R&D spending on a firm's q ratio, a measure of the relationship between the value of a firm's securities in financial markets and the estimated value of its financial assets. Morck and Yeung (1991).
46 This is discussed in National Biotechnology Advisory Committee (1998).
47 Rao and Ahmad (1994).
48 This issue is discussed in McFetridge (1995).
49 Arrow (1962).
50 These are discussed in Stoneman and Dierderen (1994).
51 Idem.
52 See Nelson and Winter (1982).
53 In a number of sectors, however, subsidies remain important. In the aerospace sector, which was excluded from the WTO Subsidy Agreement, firms cannot reasonably compete in the international market without government support. Similarly, almost all OECD countries continue to provide substantial support to R&D activities in the information technology sector.
54 Mansfield (1986).
55 Arundel and Kabla (1998).
56 See, for example, Foray (1994).
57 McFetridge (1998).
58 Cockburn and Chwelos (2001).
59 Idem.
60 Romer (1993).
61 Nelson and Romer (1997).
62 Hall and van Reenen (1999).
63 McFetridge (1995).
64 The empirical findings of one recent study examining Canadian firms' cost of capital, for example, suggests that Canadian firms may be investing more than is optimal in R&D. See Suret, Carpentier and L'Her (2001).
65 *Report of the Technical Committee on Business Taxation* (1997, Section 5.11).

66 For example, Mansfield (1990).
67 Lipsey and Carlaw (1998).
68 Two of the main earlier studies are: Tarasofsky (1985) and Usher (1983).
69 This draws on Lipsey and Carlaw (1998).
70 The features of a well-designed and administered program are discussed in Lipsey and Carlaw (1998).
71 In the case of university research support, funds are channelled through the granting councils: the Medical Research Council of Canada (MRC), the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Social Sciences and Humanities Research Council of Canada (SSHRC).
72 Government of Canada (1999).
73 Branscomb et al. (1997).
74 This was highlighted in a recent focus group organized by the Conference Board in which participants from the private sector discussed their experience collaborating with government research laboratories. Warda (1999).
75 Branscomb et al. (1997).
76 OECD (1999).
77 Government of Canada (1996).
78 For example, Metcalfe (1995).
79 David and Foray (1995).
80 Boyer, Robert and Santerre (2001).
81 For example, Saha, Love and Schwart (1994).
82 R&D consortia are discussed in Kumar and Magun (1995).
83 This issue is discussed in Newton and Magun (2001).
84 The Canada Foundation for Innovation has allocated up to $20 million to cover 40 percent of the cost of a pilot project by the Canadian Association of Research Libraries. The project will test national site licensing for the provision of electronic databases in science, engineering, health and the environment.
85 OECD, "Programs to Promote a Knowledge-Based Economy: A Summary of Selected Programs in OECD Countries," draft discussion paper.
86 This criticism was made by Tarasofsky (1985).
87 The Bayh-Doyle Patent and Trademark Amendments Act of 1980 permits performers of federally-funded research to file for patents; and the Federal Technology Transfer Act, passed in 1986 and amended in 1989, allows firms to benefit from patents for inventions resulting form co-operative research and development agreements (CRDAs) with authorized federal laboratories. These are discussed in Mowery and Ziedonis (1998).
88 Mintz (2000).
89 The factors influencing the location decisions of multinationals are discussed in UNCTAD (1998).
90 Fortin (1999).
91 Mackenzie and Thompson (1997).
92 The features of human capital and measurement problems are discussed in Laroche and Mérette (1999).
93 Over 40 percent of the population was found to perform at document literacy level 2 or less. OECD (1996a).

94 The evidence is reviewed in Betts (1998).
95 Betcherman (1992), and Betcherman, Leckie and McMullen (1997).
96 For example, Friedlander, Greenberg and Robins (1997).
97 Betts (1998).
98 The evidence from different countries is reviewed in OECD (1998).
99 Globerman, Janisch and Stanbury (1996).
100 A number of governance problems are identified in Daniels and Morck (1996).
101 This comes from Giammarino (1998). Factors impeding the operation of the market for corporate control and otherwise weakening the pressure on managers are discussed in Morck and Yeung (2001).
102 It is argued that, since Canadian venture capital funds are constrained from investing abroad, they tend to be smaller and more generalized than U.S. funds. Unlike large U.S. funds, they cannot enjoy the benefits that come from hiring experts in specific fields of scientific activity. MacIntosh (1994).
103 The relevant issues are reviewed in Mintz (2000).
104 This issue was highlighted by the Technical Committee on Business Taxation which calculated effective tax rates by taking account not just of the corporate tax rate but also of capital cost allowances, the tax treatment of inventory and financing costs, investment tax credits and other taxes on investment. Technical Committee on Business Taxation (1997).

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22

Trend Productivity and the New Economy

SUMMARY

THIS CHAPTER REVIEWS THE NEWEST DEVELOPMENTS in our understanding of the *new economy*. An emphasis is placed on the U.S. economy, given its role as the leading advanced economy. The chapter presents the different views of economists regarding this *unprecedented* performance. The evidence is that the U.S. success story is due to technological progress in the computer industry that has accelerated significantly in recent years. The point of discrepancy lies in the extent to which these new technologies have permeated the economy. The Canadian economy is also placed under examination, and its performance is compared to that of the United States. The most recent evidence suggests that the Canadian economy will see a significant pick-up in productivity growth over the next decade. In Canada, the productivity numbers for the first half of 2000 point to a revival in productivity growth. The growth rate of labour productivity (business sector output per hour) is expected to be in the 2.0-2.5 percent range in Canada over the next decade, which is twice the rate of growth experienced in the 1980s and the 1990s.

INTRODUCTION

THE PATTERNS EXHIBITED BY THE U.S. ECONOMY seem rather unusual for a country that is already considered the world productivity leader in most sectors. It is generally thought that countries that lag behind the United States are the ones with greater potential for economic improvement, and thus high-growth figures for these countries would not cause much surprise. In this era, the message unveiled by the United States is that perhaps countries with the most-developed economic environments have a greater ability to extract more output from given resources and thus, the United States *unprecedented* growth performance should be given a closer look.

Our objectives here are to examine the acceleration in U.S. economic growth after 1995; to determine to what extent information technologies (IT) have contributed to the U.S. economy's remarkable performance; and to assess the degree to which current trends are sustainable in the United States and transferable to Canada. To these ends, we lay out the cards of the advocates and sceptics of the *new economy* and analyze the grounds on which they support their arguments.

The study will also explore the contrast in behaviour of the Canadian economy, which has, until now, been excluded from the U.S. *miracle*. Before proceeding, however, we give an overview of the so-called computer productivity paradox and the notion of the *new economy*, and analyze the recent U.S. economic performance. We then provide the contrasting views of economists, followed by an examination of the Canadian productivity experience and projections for productivity growth over the next decade.

THE COMPUTER PRODUCTIVITY PARADOX

A WORD ON PRODUCTIVITY

THE MOST WIDELY-USED MEASURE OF PRODUCTIVITY is labour productivity, which measures the amount of output produced per unit of labour input; in economic terms, it is usually computed as the ratio of real gross domestic product (GDP) per hour worked. A broader measure of productivity is multifactor productivity (MFP), also referred to as total factor productivity (TFP) or the Solow residual. This term is not observed directly, but can be measured indirectly. MFP measures describe the relation between output and a wide set of inputs. Thus, if output grows faster than inputs MFP improves. As indicated by Sargent and Rodriguez (2000), in some cases MFP may be preferred over labour productivity measures, while in other cases labour productivity might prove more useful because MFP depends on arbitrary assumptions, while labour productivity is more closely related to current living standards.

THE PUZZLE

NOW THAT PRODUCTIVITY HAS BEEN DEFINED, we move on to the famous productivity puzzle presented by Nobel-prize-winning economist Robert Solow, who observed in 1986 that: "We see computers everywhere but in the productivity statistics." In recent years, the billions of dollars devoted to information technologies and the rapid spread of the Internet had been thought to be the force behind economic growth and prosperity, yet the readily available government data failed to support this fact.

Prior to 1973, the economy experienced rapid growth in labour productivity, but post-1973 data show an abrupt decline in productivity growth rates. During the 1980s, the service sector hardly showed any productivity gains despite an extraordinary burst of spending on computing equipment. Government statistics point to weak average productivity growth in this sector during this period, a distinct slowdown by comparison with previous years.

During the 1990s, a large number of researchers tried to explain this "IT paradox", by exploring and assessing different hypotheses. Explanations can be grouped into three basic categories: i) the belief that computers, although *new*, are just not that important an innovation to raise productivity growth; ii) lags in the realization of productivity; and iii) mismeasurement issues.

The mismeasurement hypothesis played a role in the decision to revise the National Accounts. If an information technology revolution exists, it should not be limited to one sector of the economy. The entire economy should benefit from these innovations. Productivity gains should thus be apparent in business-sector services, which are heavy users of IT. These industries include financial and insurance services, as well as other types of business services. Unfortunately, due to conceptual problems with the definition of nominal output as well as the construction of deflators, the measurement of output in these industries is notoriously difficult, and thus the performance of this sector is likely to be grossly understated.

It was believed that the development of appropriate measures would result in an upward revision of the productivity data, which would in part resolve the so-called computer productivity paradox.

REVISION OF THE NATIONAL ACCOUNTS

GOVERNMENT STATISTICAL AGENCIES have recently pursued new measurement initiatives, resulting in significant improvements in published macroeconomic data. On October 28, 1999, the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce released a major revision of national income accounts which changed considerably the historical data (Seskin, 1999).

The BEA recognized software as an investment and improved the measures of financial sector output to reflect product changes. As a result, a greater awareness of the impact of information technology on economic growth was moulded into the national accounts. Since measurement of labour input is fairly precise, any of the above measurement errors would show up in real output and ultimately productivity figures.

Before the October 1999 changes, the Bureau of Labor Statistics (BLS) had already made significant improvements in its measurement of the consumer price index (CPI). Clearly, any upward bias in the measurement of the consumer price index would be linked to a corresponding downward bias in the measurement of real growth. The BLS initiatives resulted in lower inflation figures than were previously employed to deflate nominal output. Gordon (2000a) estimates that these revisions reduced the upward bias in the CPI to a range of 0.65 percent down from the previous 1.1 percent for the period 1995-96.

The upward revisions to real GDP growth seem to be concentrated in the post-1980 period. For the period 1982-89, real GDP figures were revised upward by an average of 0.31 percentage points per year, and for the period 1990-95, by 0.46 percentage points per year. This pace continued in the 1996-98 period, which experienced a 0.50 percentage points increase. It is evident that the revision has resulted in a greater pace of expansion than was shown in previously-published real GDP growth estimates.

The outcome supports *new economy* proponents, as the revised numbers provide some evidence of the early impact of the information revolution, and thus paint a more coherent picture of the past two decades. As output gains translate on a one-to-one basis into productivity gains, it is not surprising that the old data showed long-term growth in productivity, or output per worker for the total economy, slumping to about a 1 percent annual rate in the mid-1970s, a trend that extended well into the 1990s. The new data show that output per worker started to grow faster in the 1980s and steadily picked up speed in the 1990s, mainly since 1995.

With the release of the new statistics, it seemed that the computer productivity paradox had been resolved. As Gordon (2000c, p. 1-2) indicates: "Economists struggling to explain Solow's paradox looked up from their word processors to discover that, before they had satisfactorily explained it, the paradox had been rendered obsolete both by data revisions and by the exploding rates of productivity growth registered in 1998 and 1999." Yet, this was not the end of the dispute between the proponents and the sceptics of the *new economy*. The new evidence had brought the debate to a whole new level.

WHAT IS NEW IN THE *NEW ECONOMY*?

DEFINITION OF THE *NEW ECONOMY*

SOME DISAGREE THAT THE ECONOMY HAS CHANGED. But the economy is always changing. A quick glance at recent data on the U.S. economy indicates that something peculiar is afoot. The notion of a *new economy* has been used to indicate that perhaps our understandings of the rules and principles that underlie an economy's behaviour have significantly changed in ways that are different from those of the *old economy*. The question simplifies to whether the current period of change is fundamentally different in some way from earlier periods.

The term *new economy* is a rather elusive concept and lends itself to different interpretations. What is clear is that this concept is closely tied to the effects of technological progress, in particular the linkage of stronger non-inflationary growth to the rising influence of IT. There are different aspects and thus different definitions of the *new economy*. The preferred one, used in this study, defines the *new economy* as changes in trend productivity.

Proponents of the *new economy* argue that the economy is now different, or new, because of a significantly higher *long-term* or trend productivity, which has been brought about by the extensive application of IT across a wide range of sectors, resulting in a restructuring of economic activities. The sceptics argue that the recent productivity surge is transitory and does not usher in a 20-25 year period of strong productivity growth.

Overall Productivity Trends in the United States

SINCE 1995, PRODUCTIVITY GROWTH has accelerated in the United States. This became apparent as output growth revealed remarkable strength, while unemployment fell to its lowest level in thirty years. The core consumer price index has only risen 2.25 percent over the last twelve months, indicating that inflation is showing no sign of perturbing the economy.

The Federal Reserve Board has been rather aggressive in probing the limits of the non-accelerating inflation rate of unemployment (NAIRU). This resulted in robust demand growth and allowed the increase in potential output arising from the IT revolution to manifest itself as actual output. The low unemployment rate has given employers an additional incentive to substitute capital for labour, resulting in full utilization of human resources, much to the benefit of labour productivity.

As labour productivity continued to surge, economists began to question the stylized facts of productivity growth behaviour across the business cycle. Productivity growth usually picks up early, as the economy expands, and slows later into the expansion. For the U.S. economy, however, there did not seem to be such a productivity slowdown.

Table A1 (in the Appendix) provides data on labour productivity and other related variables. A look at productivity growth rates provides ample evidence of the productivity surge since 1995. The series on real value-added is produced by the BEA, and statistics on the number of employed persons in the total economy come from the *Economic Report of the President* (2000), based on the Current Population Survey.

The data indicates that real value-added per person employed advanced at an annual rate of 2.4 percent during the 1995-99 period, twice as fast as the rate of 1.2 percent of the 1989-95 period and 0.9 percentage points higher than the 1.5 percent rate of the 1981-89 period.

According to the most widely-used official aggregate productivity measure — the series on business sector output per hour produced by the BLS — productivity increased at an average annual rate of 1.2 percent from 1989 to 1995. During the 1995-99 period, it advanced at an average annual rate of 2.7 percent and a stunning 4.6 percent annual rate in the first half of 2000 (Table 1).

A glimpse at the manufacturing sector data reveals one of the main sources of the economy-wide productivity revival. Production in this sector is responsible not only for the greater numbers but also for the superior quality of computing equipment that sent computer prices plunging. This encouraged *capital deepening*, defined as a rate of increase of the capital input in the economy faster than that of the labour input, resulting in the use of proportionally more capital to labour to produce national output.

In the manufacturing sector, the growth in real capital stock over the 1995-98 period was nearly double the growth rate for the 1989-95 period, and 1.7 percentage points higher than the growth rate for the 1981-89 period (see Table A1). This inevitably translated into the economy-wide data, where growth in real capital stock increased by one percentage point between the 1989-95 and the 1995-98 periods.

The Productivity Experience of the Service Sector

THE MAJORITY OF COMPUTERS PRODUCED are used in the service sector, by industries such as finance, insurance and real estate; retail and wholesale trade; transportation and public utilities; government services; and other service industries. If there is to be an acceleration in technological progress, productivity gains should extend to these IT-using service industries.

Productivity data for the service and goods sectors are constructed from the real output and labour input series compiled by the BEA. These are presented in Table 2.

The data clearly emphasize the significant role played by the service sector in fuelling the productivity revival. After many decades of stagnant growth, there now appears to be a renaissance in service sector productivity. Real value added per person employed in the broadly-defined service sector advanced at an average annual pace of 2.3 percent during the 1995-99 period, up nearly five-fold from the 0.5 percent rate of the 1981-89 and 1989-95 periods.

TABLE 1

U.S. BUSINESS SECTOR: OUTPUT, LABOUR PRODUCTIVITY AND PRODUCTIVITY ELASTICITY

	Indices: 1992=100		Annual Rate of Change		
	Output per Hour	Output	Output per Hour	Output	Productivity Elasticity
1949	35.9	23.0	—	—	—
1973	78.0	61.3	—	—	—
1981	85.4	74.5	—	—	—
1989	95.5	97.8	—	—	—
1990	96.1	98.6	0.63	0.82	0.77
1991	96.7	96.9	0.62	-1.72	-0.36
1992	100.0	100.0	3.41	3.20	1.07
1993	100.1	102.7	0.10	2.70	0.04
1994	100.6	107.0	0.50	4.19	0.12
1995	102.6	111.5	1.99	4.21	0.47
1996	105.4	116.4	2.73	4.39	0.62
1997	107.6	122.5	2.09	5.24	0.40
1998	110.5	128.6	2.70	4.98	0.54
1999	114.0	134.8	3.17	4.82	0.66
2000 (est.)*	119.2	143.6	4.56	6.53	0.70
			Year over Year		
2000Q1	116.7	140.3	3.64	6.05	0.60
2000Q2	118.7	142.4	5.23	6.10	0.86
2000Q3	119.5	143.3	4.64	5.91	0.79
			Average Annual Rate of Growth		
1949-73	—	—	3.29	4.17	0.79
1973-81	—	—	1.14	2.47	0.46
1981-89	—	—	1.41	3.46	0.41
1989-95	—	—	1.20	2.21	0.54
1995-99	—	—	2.67	4.86	0.55
1995-2000*	—	—	3.04	5.19	0.59
			Quarterly Growth at Annual Rate		
2000Q1	—	—	1.38	5.30	0.26
2000Q2	—	—	7.03	6.12	1.15
2000Q3	—	—	2.72	2.55	1.07

Note: * Data for the year 2000 are calculations based on the first three quarters of 2000 under the assumption of a continuation of current trends.

Source: Output per hour and output data come from the BLS: data fot 1948-97 are obtained from http://www.bls.gov/news.release/prod3.t01.htm, Feb 1999; data for 1998-2000Q3 are obtained from http://www.bls.gov, last modified, December 6, 2000.

TABLE 2

GROWTH RATE OF VALUE ADDED PER WORKER EMPLOYED, UNITED STATES

	AVERAGE COMPOUND GROWTH RATE			
	1981-89	1989-95	1995-99	(1995-99)-(1989-95)
Total Economy	1.38	1.11	1.98	0.87
Goods Sector	3.18	2.20	3.23	1.03
Agriculture, Forestry and Fishing	3.60	0.01	5.18	5.17
Mining	8.02	4.71	4.01	-0.70
Construction	0.64	-0.13	-0.03	0.09
Manufacturing	3.74	3.14	4.41	1.28
Service Sector	0.48	0.54	2.29	1.75
Transportation and Public Utilities	2.21	2.59	1.66	-0.93
Wholesale Trade	3.37	2.85	8.19	5.35
Retail Trade	1.61	0.91	5.20	4.29
Finance, Insurance and Real Estate	-0.12	1.64	2.86	1.22
Services	-0.16	-0.79	0.28	1.07
Government	0.33	0.28	0.69	0.41

Notes: a) Because of the use of non-additive chain indices for real output, and the independent derivation of GDP and industry GPO estimates, industries' total GDPs do not sum up to the economy-wide total. As a result, the total economy productivity growth rate for the 1995-99 period is less than both the goods sector and service sector productivity growth rates.
b) Chained-dollar GDP aggregates for the goods and the service sectors have been obtained by summing the chained-dollar industry estimates in each respective group. This is a close approximation, although a better one would be obtained by a "Fisher of Fishers" aggregation.

Source: Data for GDP come from the Bureau of Economic Analysis, 2000. Release date: December 2000. http://www.bea.doc.gov/bea/uguide.htm#_1_14; GDP data for 1998 and 1999 were taken from http://www.bea.doc.gov/bea/dn2.htm.

A more disaggregated analysis illustrates that four of the six basic service sector industries have registered at least a one percentage point increase in labour productivity growth between the 1989-95 and 1995-99 periods. The growth rate of output per worker in wholesale trade accelerated 5.4 percentage points, in retail trade 4.3 percentage points, in finance, insurance and real estate 1.2 percentage points, and in services (personal, business and other services) 1.1 percentage points. Even government services enjoyed higher productivity growth, up 0.4 percentage points, although the estimates of real output for government are not appropriate for productivity calculations as they are largely estimated on the basis of inputs. The only service sector industry that did not enjoy faster productivity growth after 1995 was transportation and public utilities, which showed a 0.9 point decline.

Although productivity growth in the goods sector continues to outperform that of the service sector — 3.2 percent versus 2.3 percent per year in the 1995-99 period — the goods sector productivity did not pick-up after 1995 from its robust pace of the 1989-95 period. During these two periods, the goods sector experienced an acceleration in productivity growth of 1.0 percentage points, which is lower than the 1.8 percentage points acceleration observed for the service sector. This reflects the strong productivity growth in manufacturing and mining during the first half of the 1990s.

Until recently, it was believed that most productivity gains were taking place in the IT-producing sector, and that the productivity-enhancing impact of IT was not spreading to the IT-using sectors. With the renaissance of productivity growth in IT-using service industries such as wholesale and retail trade, it now appears that the acceleration of productivity growth is broadly based. The lags between IT investment and productivity appear to have ended as firms and workers have now learned to use these new technologies in an effective manner. The large IT investment in wholesale and retail trade and the very strong increases in productivity observed in these two industries support the IT story. The service sector productivity drought is over, at least for the second half of the 1990s, and possibly for the future.

ALTERNATIVE VIEWS OF THE *NEW ECONOMY*

OVERVIEW

FOLLOWING THE RELEASE of the newly-revised output figures coupled with the evidence of a strong U.S. economy, many *new economy* sceptics turned into converts. Yet, sceptics still remain. The point of disagreement between the two groups is not about the role of IT in boosting the economy's overall productivity, but the issue of sustainability of current productivity trends, and the extent to which the technological revolution has been incorporated into the economy.

The proponents of the *new economy*, which we define as an upward structural shift in long-term productivity growth, point to the recent strong productivity experience of the United States. The productivity surge, which traditionally takes place at the beginning of the business cycle when the economy expands, has endured even at the end of the cycle. Moreover, the extensive investment in IT technologies has resulted in higher productivity for the IT-using sector. This broadening of productivity gains since 1995 augurs well for the acceleration of technological progress in the economy and indicates that such long-term productivity gains are within the realm of possibility.

The sceptics argue against the *new economy* view by indicating that the productivity gains are highly concentrated in the IT-producing sector. They view the U.S. productivity experience as a short-term phenomenon by indicating that the great price decline of computers and related information technology products has resulted in diminishing marginal productivity. By comparing these new technologies to the general purpose technologies of the past, they point out that IT is relatively far less crucial.

THE 'ADVOCATES' CASE

> At Macroeconomic Advisors, we initially viewed the acceleration of productivity as a transitory cyclical event because our then current econometric models suggested so. However, nearly three years later, the persistence of strong productivity growth sheds increasing doubt on that interpretation.
> *Macroeconomic Advisors*, 1999.

FOR MOST OF THE 1990S, THE MAJORITY OF ECONOMISTS rejected the notion of a *new economy* as characterized by higher trend productivity growth. With the acceleration of productivity growth in both the service and goods sectors since 1995, they hurriedly became converts. In the process, economists have been hard pressed to understand the contribution of the technological revolution to this phenomenal growth.

An overwhelming body of analysis suggests that IT-using sectors have played a major role in fuelling economy-wide productivity growth. The substantial usage of the Internet and e-commerce must also be taken into account. Many analysts consider that it is these technologies that have improved efficiency in virtually all sectors of the economy. The following is a survey of the views of the advocates of this *new era* and their beliefs about how information technology has permeated the entire economy.

Oliner and Sichel (2000)

In a recent paper, Stephen Oliner and Daniel Sichel (2000), two economists at the Federal Reserve Board in Washington known for their analytical work on the economic impact of computers, re-assess the role played by information technology in influencing productivity statistics. Their paper, entitled *The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?*, is much like their previous research, in which a neoclassical growth model was used to examine the contribution of computers and related inputs to growth. Using available evidence, Oliner and Sichel (1994) and Sichel (1997) found that through the early 1990s, computers should not have been expected to make a significant contribution to output growth, simply because computing equipment represented only a small fraction of the total capital stock at the time.

However, things have changed since their earlier research. The stock of computer equipment has increased dramatically, and as estimated, seem to be earning greater returns than in previous years. Furthermore, the computer-producing sector seems to have achieved a higher degree of efficiency. In their previous work, these authors had concentrated on calculating the growth contribution of information technology through computer hardware and software. In their new research, they choose to increase the complexity of their work by including communications equipment, which would provide a better understanding of the role of information technology on the economy.

Their study is divided into two main sections: the first analyzes the impact of the use of information technology on output and productivity growth, and the second estimates the impact of the production of computers on growth.

Their recent results somewhat differ from those of their previous research, which had shown a relatively small impact of information technology on real output and labour productivity growth through the early 1990s. Although the years 1991-95 saw an average annual output growth rate of around 3 percent and labour productivity growth of 1.6 percent, computer hardware and software each only accounted for a fifth of a percentage point per year of that growth. Communications equipment had a lesser impact. It contributed only 0.05 percentage points per year during that period.

Things looked different during the second half of the 1990s. The contribution of information technology capital to output growth swelled. The contribution of computer hardware to output growth over the years 1996-99 was now about 0.6 percentage points per year, two and a half times greater than during the 1991-95 period. Overall, the contribution of information technology capital (hardware, software and communications equipment) to output growth was about 0.9 percentage points, which is a remarkable increase compared to the previous period.

Capital deepening related to information technology capital accounted for 0.5 percentage points of the 1.1 percentage point increase in labour productivity from the first half to the second half of the 1990s, thus contributing nearly half of the total increase in labour productivity. MFP accounted for the rest of the increase.

A look at the computer-producing sector, defined as the sector that produces IT capital, indicates that technological advances in this sector, including the production of the embedded semiconductors, appear to have made important contributions to the surge in MFP growth.

In order to arrive at more precise estimates, Oliner and Sichel divided the non-farm business sector into three sub-sectors. One that produces computers, another that produces semiconductors, and the last consisting of all other non-farm industries. After solving for the three sectoral MFP growth rates, they find that the contributions from computer and semiconductor producers had increased considerably during 1996-99, reaching 0.22 and 0.41 percentage points per year, respectively. Their values during 1991-95 had each been 0.13 percentage points per year.

The authors point out that these increases are mainly due to the sharp decline in the relative prices of computers and semiconductors during the period, depicted as an increase in MFP growth in their framework. This is because they estimate MFP growth with what is called a *dual* method, which uses data on the prices of output and inputs — rather than their quantities — to calculate MFP growth. Through an example, they explain how this method can be implemented. If output prices for a certain good such as semiconductors drops sharply over time, while input prices remain stable, then MFP growth in semiconductor production must be rapid compared to other sectors. Otherwise, semiconductor producers would be driven out of business due to the lower prices of their outputs and unchanged input costs.

Overall, the results obtained by Oliner and Sichel indicate that information technology has been the primary force behind the rapid gains in productivity after 1995. The authors attribute about a quarter of a percentage point of the overall acceleration in productivity to the computer industry's own production processes. They also estimate that the growing use of information technology capital by all other firms in the non-farm business sector accounts for almost half of the recent rise. Together, these factors contribute to about two-thirds of the rise in labour productivity growth since 1995. The growth in other capital services explains less than 0.05 percentage points of this acceleration, while MFP growth in the remainder of the non-farm business sector makes up for the rest.

It should be noted that their analysis (as well as the ones that follow) excludes the impact of IT chips embodied in non-computer technologies such as automobiles and trucks. Any productivity-enhancing effects from the use of IT chips by *other* industries would not be accounted for in the contribution of IT to productivity growth. By including the productivity effects of IT chips in non-computer industries, not just the part that feeds into the computer industry, would give more credit to the influence of information technology on overall productivity.

However, their analysis depends heavily on the assumptions behind the neoclassical framework. In this model, businesses are rational and thus always make optimal investment decisions. This implies that all types of capital earn the same competitive rate of return at the margin, net of depreciation and other costs associated with owning each asset. Although deviations from this assumption are likely, it is nonetheless a satisfactory approximation of reality. Their study suggested that there is not, and never was, a productivity paradox, and time has proved it. In effect, technological innovation has been the primary force behind the resurgence of productivity growth.

Jorgenson and Stiroh (2000)

Similar views are shared by Dale Jorgenson of Harvard University and Kevin Stiroh of the Federal Reserve Bank of New York, who have recently become *new economy* converts. In a recent study, *Raising the Speed Limit: U.S. Economic Growth in the Information Age* (2000), they lay out their findings and make a clear case for raising the U.S. economic speed-limit. They hold technological progress in the IT-producing sector as well as the greater investment and use of these high-tech equipment by the business service industries, responsible for the recent growth resurgence.

They state that the technology sector has realized greater efficiency gains, and thus has become so much more productive over the past decade, and grown so much as a percentage of the economy, that it has lifted productivity for the entire economy. However, they found little evidence of a MFP spillover to the IT-using industries, and thus they provide a note of caution: "The evidence is clear that computer-using industries like finance, insurance and real-estate, and other services have continued to lag in productivity growth. Reconciliation of massive high-tech investment and relatively slow productivity growth in service industries remains an important task for proponents of the *new economy* position." (Jorgenson and Stiroh, 2000, p. 128)

Jorgenson and Stiroh's analysis implies that the greatest gains in productivity growth have come from technological progress rather than labour quality or capital investment. As found by Oliner and Sichel (2000), the absolute contribution to productivity growth from labour quality fell in the second half of the 1990s by about 30 percent, compared to the first half of the decade.

From 1995 to 1998, the average annual rate of growth in average labour productivity was 2.4 percent, up one percentage point from the 1.4 percent rate of the 1990-95 and 1973-90 periods, and only 0.6 percentage points lower than in the 1959-73 period. Capital deepening accounted for almost half of this increase, a result also obtained by Oliner and Sichel (2000). Moreover, the contribution of TFP to labour productivity during 1995-98 was one percent, nearly three times greater than in the 1973-90 and 1990-95 periods. For the 1990s, the contribution of TFP is further decomposed. Their estimates indicate that the production of IT accounts for 0.4 percentage points of TFP growth in the 1995-98 period, compared with 0.25 percentage points in the first half of the decade.

Jorgenson and Stiroh find that TFP growth increased from 0.36 percentage points per year, during 1990-95, to 0.99 percentage points, on average, over 1995-98. This mainly reflects the sharp decline of computer prices, which began in 1995 due to greater competition in the semiconductor market. As noted by the authors, this decline averaged 28 percent per year from 1995 to 1998. As a result, the economy experienced massive computer investments as, according to Jorgenson and Stiroh, "firms and households substituted towards relatively cheaper inputs."

In order to form a basis of comparison with the above study, Jorgenson and Stiroh find that during 1995-98, computer hardware contributed 0.36 percentage points annually to output growth. This estimate is less than that suggested by Oliner and Sichel. The former argue that the reason for this divergence is probably that they use a broader concept of output than the one employed by Oliner and Sichel. As a result, computer hardware has a smaller income share. They also assume that machines only become productive with a lag. This makes their results lagged by one year, and their estimates for growth thus reflect lower rates.

All in all, Jorgenson and Stiroh's motto is: "As long as high-tech industries keep innovating and improving their productivity, the economy should be able to sustain a high rate of productivity growth, and thus the virtuous circle of an investment-led expansion will continue." (Jorgenson and Stiroh, 2000, p.128)

THE 'SCEPTICS' CASE

> If anything is clear, it is that however unimportant the computer is today in generating productivity growth, we can be sure that at the margin it was more important a decade ago and will be less important a decade hence, simply because continuing exponential declines in the cost of computer power push incremental increases in computer power into lower and lower productivity uses.
>
> Robert Gordon (1999)

EVEN THOUGH ADVOCATES OF THE *NEW ERA* have presented their case clearly, not all economists have become *new economy* converts. Sceptics remain, though their numbers has been seriously reduced. The shorter size of this section as compared with the previous one, qualifies as proof.

Sceptics generally have a pessimistic view of the Internet, indicating that much Internet activity is simply a waste of time. They argue that even if the Internet does transform the way firms do business, it does not mean that they will enjoy outstanding profits. Much of the benefit of the Internet is simply redistributed and mostly accrues to consumers in the form of greater convenience and perhaps a different channel of entertainment.

Gordon (2000b)

Robert Gordon, of Northwestern University, has been the most outspoken *new economy* sceptic. In a widely-cited study circulated last year (Gordon, 1999), he pointed out that the recent surge in labour productivity growth was entirely due to the computer-manufacturing industry and the low payoff to computer investment in most parts of the economy where computers are used, indicating that the Solow paradox is still pertinent.

Gordon (2000b) supports his findings by arguing that the so-called new inventions fall short of the innovations of the past. This idea is well expressed in his paper entitled: *Interpreting the 'One Big Wave' in U.S. Long-term Productivity Growth*. As the title suggests, he sees the economy evolving through time as one *big wave*. He paints that picture by stating that: "MFP growth exhibits a symmetric wave that peaks in 1928-50 and slows gradually moving backwards to 1870-91 and forward to 1972-96." He lays out the hypothesis that the wave peaked during these years due to important inventions that occurred at around the same time. He does not believe that the wave would rise again, at least not in the near future.

As for the Internet, Gordon has a more pessimistic view of its productivity-enhancing effects than other analysts. Since many economists view 1995 as the year when productivity growth took off, Gordon asserts that for the past five years, the growth in demand for computers should have increased relative to the decline in computer prices. But his results suggest otherwise. Furthermore, when compared to electric light and electric motors, computers experienced a higher rate of price decline, which indicates that they are diffusing into the economy at a faster rate than these previous inventions. Also, since they were relatively more reliable from the beginning, diminishing returns are likely to set in much faster.

He acknowledges that the Internet provides information and entertainment more cheaply, but much of its use involves a duplication, rather than a replacement of existing activities. This disqualifies the Internet as a *first-order* invention, and thus makes it different from the inventions of the past, which created brand new products and activities. The other downside of the Internet as far as businesses are concerned is that the development of web sites and maintenance and upgrading costs of computers are more likely to raise costs than revenues. Such investments by firms in computer infrastructure are driven by the need to protect market share against competitors. He suggests that, unlike computers, humans have not been faced with exponential growth in speed or memory. Even if it takes the computer less time to open and save files, human beings can only think and type at a certain rate. He points out to the growing evidence on usage of the Internet for personal purposes during work time, which serves to distract workers and could reduce their productivity.

At the end of his paper, Gordon makes an effort to re-emphasize the idea previously put forward by Triplett (1999a,b). As implied earlier, the fact that a greater number of products exist than before is simply not enough. What economists should look at is the rate of new product creation and not the number of new products.

The question that undoubtedly passes the minds of many at this point is why does Gordon reach a conclusion that is somewhat different from most economists? First of all, Gordon's paper was written before the publication of newly revised economic data, and thus shows a substantially lower productivity growth for the overall economy. The paper's conclusion has since been modified with the release of the revised national income and product accounts (NIPA) statistics in 1999; based on the new data, his results for the computer-producing industry are much in line with those of Oliner and Sichel. However, he still sees little, if any, productivity growth in the non-farm business sector excluding durables manufacturing, which is where computers end up (Gordon, 2000d). This conclusion differs from that of most *new economy* advocates.

Although his new figures provide a more plausible picture of the economy, Gordon still rejects the idea of a *new economy*. His final estimates are based on cyclical adjustments, which he describes as follows: "The decomposition of the recent productivity acceleration between cycle and trend is accomplished by specifying a value for the hours growth trend (h^*) and then conducting a grid search to find the output growth trend (y^*) that optimizes the fit of the equation explaining the relation of $h-h^*$ to $y-y^*$." (Gordon, 2000d, p. 218)

After this decomposition, Gordon attributes 0.5 percentage points of the 2.9 percent annual productivity growth in the non-farm private business (NFPB) sector to cyclical effects, and the remaining 2.3 percentage points to trend growth, which is 0.8 percentage points faster than the 1972-95 trend. He then explains that a small part of this acceleration in trend growth is attributable to changes in price measurement methodologies and to a slight acceleration in the labour composition effect. The remaining 0.62 percentage points is attributed to structural acceleration in labour productivity, of which 0.3 percentage points are accounted for by capital deepening and the other 0.3 percentage points are the resulting effects of the acceleration of MFP in computer and computer-related semiconductor manufacturing.

After subtracting output and hours in computer manufacturing from the NFPB sector, structural acceleration in labour productivity is 0.19 percentage points less than the total NFPB economy. MFP in this sector faces a structural deceleration of 0.09 percentage points, indicating the absence of spillover effects on MFP in the part of the economy that excludes computers.

Furthermore, the disturbing fact remains that in the greater part of the U.S. economy that constitutes non-farm business services, there is only a

0.05 percentage points per year cyclically-adjusted productivity growth. In plain words, this is almost nothing. There is no MFP growth acceleration outside the computer industry. The other sectors were just not hit by the great miracle. As Gordon points out, the Solow paradox seems to have somehow survived in the part of the economy where computers end up after production.

Whether he uses the new or the old figures, Gordon's stand on productivity is clear: "The optimists declare the arrival of a 'new economy' in which the benefits of the hi-tech revolution and globalization will bring about a revival of rapid growth, but in my view the remorseless progression of diminishing returns has left the greatest benefits of the computer age in the past, not awaiting us in the future." (Gordon, 2000b, p.45)

Comments by the Opposing Sides

In response to Gordon's findings, most Federal Reserve economists, including Oliner and Sichel, who try to explain the surge in actual productivity and not cyclically-adjusted productivity are suspicious of his adjustment techniques for the business cycle. They note that: "Separating cycle from trend is difficult, particularly in the midst of an expansion."

They add that the rise in actual productivity growth cannot be entirely due to the production of computer hardware by the computer-manufacturing industries. The use of computers should also be credited with a contribution to the acceleration in productivity after 1995. Gordon's reply is that output grew more than trend in the 1990s, and so productivity must have grown faster than trend since the economy benefited from falling unemployment. Even recently, the economy has been growing faster than the new higher speed-limit; consequently, some of the recent rise will turn out to be transitory.

Although there seems to be a distinct contrast between Gordon's paper and those of Jorgenson and Stiroh and Oliner and Sichel, Gordon implies that there is in fact little disagreement between the three papers (Tables 3 and 4). He adds that his research on cyclical impacts does not affect the paper's decomposition of input growth into the relative contributions of IT capital, non-IT capital, labour hours, and labour composition. What his research implies however, is that the post-1995 TFP acceleration is likely to be temporary, due in part to the onset of diminishing returns which, by shifting down the cost curve, rapidly brings down firms' demand for IT products and moves them to lower marginal utility uses.

TABLE 3

JORGENSON AND STIROH VS OLINER AND SICHEL: ALTERNATIVE ESTIMATES OF THE SOURCES OF ACCELERATION IN LABOUR PRODUCTIVITY
(PERCENTAGE POINTS PER YEAR)

	JORGENSON AND STIROH (2000)* 1995-98	OLINER AND SICHEL (2000) 1996-99
Labour Productivity (Non-farm Business Sector)	1.0	1.0
Capital Deepening	0.5	0.5
Information Technology	0.3	0.5
Other	0.2	0.0
Labour Quality	-0.1	-0.1
Multifactor Productivity	0.6	0.7
Production of IT	0.2	0.3
Other	0.4	0.4

Note: * Jorgenson and Stiroh employ a broader concept of output than Oliner and Sichel. In their output series, they include imputed service flows from owner-occupied housing and consumer durables.
Source: Sichel, 2000, p. 223.

TABLE 4

GORDON'S ESTIMATES OF THE SOURCES OF ACCELERATION IN LABOUR PRODUCTIVITY
(PERCENTAGE POINTS PER YEAR)

	CONTRIBUTION TO PRODUCTIVITY INCREASE
Actual Acceleration in Labour Productivity, 1972-95 to 1995-99	1.4
Trend Acceleration (including CPI adjustment)	0.7
Contribution from:	
Capital Deepening	0.3
Labour Quality Improvement	0.1
Multifactor Productivity	0.3
Production of IT	0.3
Other	0.0

Source: Sichel, 2000, p. 223.

The story told by the first two papers is broadly similar. The only difference is in regard to the estimate of the contribution of IT to the acceleration in labour productivity. Oliner and Sichel find the value of this contribution to be 0.5 percentage points, which is considerably larger than the 0.3 percentage points estimated by Jorgenson and Stiroh.

Gordon's estimates of IT's contribution to growth are much in line with those of the other two studies. For capital deepening and MFP growth from the production of computers, his estimates line up closely with the other papers. The reason why they do not match closely the values in Table 3 is that Gordon's study considers a different time period than the other two studies. The difference lies in the fact that Gordon attributes all of the acceleration in MFP to the IT-producing sector, leaving nothing to the non-computer economy. Jorgenson and Stiroh and Oliner and Sichel find that MFP growth elsewhere in the economy accounts for 0.4 percentage points of the acceleration.

THE DEBATE CONTINUES

ECONOMISTS TAKE STRONG STANDS in supporting their views. By reviewing the different views of the importance of information technology, it is clear that much room remains for debate. *New economy* advocates criticize Gordon's belief that IT does not measure up to the inventions of the past. They assert that information technology has, in fact, some advantages over previous technological revolutions. For example, railways solely affected the movement of goods, whereas the Internet is not restricted to such a limited area of the economy. The Internet has simply a lot more to offer. It affects most spheres of activity of firms and households. It is a new form of communication, an efficient information system, a new marketplace and a new means of distribution.

A second factor is that patience is required until we can observe that new technology lifts productivity growth. Gordon's patience has long ran out, as he states in his papers that all the benefits of information technology lie in the past, not awaiting us in the future. He sees the great reductions in computer prices as a factor supporting his argument.

Conversely, productivity optimists claim that rapidly falling computer prices could be seen as a positive factor. It is true that computer prices have fallen more rapidly than any previous technology, but that does not mean the benefits of computers have already arrived. The computer revolution started 50 years ago with the invention of the transistor, but economic history suggests that productivity gains from new enabling technologies diffuse only gradually across the economy. The rapid decline in computer prices accelerated only recently — after 1995 — and set off the extensive spread of the Internet, which encouraged firms to adopt this new technology more quickly. By looking at the productivity picture through this light, it can be said that most of the economic benefits of these new technologies are still ahead of us, and not behind.

Another factor that enters the debate is the business-cycle adjustments employed by Gordon. Advocates of the *new economy* argue that cyclical adjustments might generate biased results. Moreover, the information revolution is likely to have affected the cyclical behaviour of the economy in ways not yet fully comprehensible. As a result, any cyclical adjustments could have a negative impact on the importance of information technology in the economy.

Furthermore, they note that, as the years pass and productivity growth continues to surge, it is becoming increasingly implausible to assert that these changes are simply one-time developments or a simple cyclical phenomenon.

Another point of discrepancy is the permanence of these developments. Lawrence Klein, professor emeritus of economics at the University of Pennsylvania and a Nobel-prize-winning economist, believes that policymakers have underestimated the impact of technology on productivity and that productivity gains should continue for another ten years.

By contrast, sceptics view the productivity surge as just a blip. Peter Dungan, Steve Murphy and Thomas Wilson (2000, p. 1) state that: "We do not project that the industrial economies (or at least the North American ones) are now undergoing or are about to undergo a structural shift in which computer and communications technology will lead to permanently higher long-term productivity growth."

By observing the different approaches taken by economists on this topic, a definitive answer to the question of whether the U.S. economy has entered a new era of sustainable growth or whether it has benefited from temporary or cyclical influences is not possible at this stage. However, the recent evidence on the U.S. economy, which points to increased productivity growth for the computer-using sector, as well as the arguments put forward by proponents of the *new economy* augurs well for an economy characterized by a significantly higher trend productivity growth.

THE CANADIAN PRODUCTIVITY EXPERIENCE

PITFALLS IN INTERNATIONAL PRODUCTIVITY GROWTH COMPARISONS

BEFORE EXAMINING THE PRODUCTIVITY EXPERIENCE of the Canadian economy and providing a basis of comparison to the U.S. productivity experience, it must be noted that any measurement issues raised by observing a single economy worsen when attempting to make international comparisons. At the international level, data problems limit the possibility of making reliable comparisons of growth performance across countries. Different national statistical agencies adopt different methodologies and data definitions. As a result, it becomes very difficult to make international comparisons on a consistent and meaningful basis.

The first of these output measurement issues is related to the independence of output from input measures (Scarpetta, Bassanini, Pilat and Schreyer 2000, p. 85). Since productivity is measured using data on the output of the economy, any error occurring in output measurement would be reflected in the productivity figures. In principle, output and input indices are calculated and constructed independently. Yet, dependence between the two can occur, especially when the output series are based on input measures. Input-based estimation is more frequent in service sector industries, particularly the non-marketed services. By construction, either productivity growth in these sectors would be zero, or would reflect the assumptions made by statisticians. This downward bias brought about by the use of inputs has different consequences in different countries, depending on the incidence of use, and thus could hinder cross-country comparisons.

The second issue in output measurement involves the use of chained or fixed-weight index numbers. A choice of these indices must be made when comparing price or quantity over two different periods. In the fixed-weight index, the first or last observation is chosen as the base. In the chain index, the base changes at every period as the chain is applied by linking either price or quantity indices for consecutive periods. Much of the literature supports the use of chained indices for they are able to capture changes in relative price structures. For example, in the case of information technology products, rapidly changing prices can render fixed weights obsolete resulting in significant biases in the measurement of prices and quantities. To date, only a small number of countries, such as the United States, have adopted chain-weighted indices. The results for these countries are not consistent with those of countries that employ fixed-weight indices.

Countries also differ strongly in their statistical treatment of quality improvements in IT goods. Hence, the last of these measurement issues is concerned with the construction of computer deflators. The sharp drop in computer prices in the United States reflects the use of hedonic methods, whereas the slight decline or even increase in the prices of computers and related equipment in many European countries may be due to a lack of adjustment for these quality changes. This method is not employed by some countries because the construction of hedonic price deflators can be quite costly.

Furthermore, in revising the U.S. National Accounts, the decision made to treat software as an investment good led to a significant boost in their productivity growth figures, especially for the 1995-99 period. Canada and Europe have not yet adopted this methodology. Consequently, the growth rate of output of countries that continue to treat software expenditures as an intermediate good rather than as an investment is likely to exhibit a downward bias, which is reflected in the productivity measures.

As a result of these measurement issues at the international level, the comparability of output measures is far from perfect, for the superior statistical methodologies employed by the United States have rendered their productivity data less comparable than they were with that of other countries. Hence, international comparisons of output and productivity growth have to be treated with great caution and should only serve as rough benchmarks.

Overall Productivity Trends in Canada

By looking at productivity growth trends in Canada and the United States, one can easily see that the two economies have gone through similar phases in the past. Both enjoyed robust productivity growth after the Second World War up until 1973. They then experienced a slower trend productivity growth. However, much has changed during the 1990s. The Canadian productivity performance in this decade, particularly since 1995, is in marked contrast to that of the United States. It is clear that this side of the border has not experienced the productivity miracle of the United States. Yet, recent evidence points to the likelihood that Canada will enter the *new economy* of higher trend productivity in the near future.

Although the Canadian economy did accelerate in the second half of the 1990s, the increase in output is almost entirely accounted for by increased employment, not productivity gains. This development in itself is not necessarily bad — some may even say it is positive — as employment growth is highly desirable because it reduces the unemployment rate and labour market slack and has beneficial effects on the government's fiscal position. Nevertheless, it raises the question of why productivity growth was so poor, particularly in comparison with the U.S. experience.

This is illustrated by Table A2 in the Appendix. The productivity data were constructed by the Centre for the Study of Living Standards (CSLS) from real GDP and labour input data compiled by Statistics Canada. As can be seen, real GDP accelerated 1.9 percentage points to reach an average annual growth rate of 3.4 percent between 1995 and 1999, from only 1.5 percent in the 1989-95 period. Between these periods, employment growth accelerated 1.7 percentage points, from an average annual rate of 0.5 percent to 2.1 percent. Productivity growth, measured in terms of GDP per worker, was up by only 0.3 percentage points, while GDP per hour decelerated by 0.5 percentage points.

The productivity performance of the Canadian business sector is in sharp contrast with that of the United States. Statistics Canada data show that this sector's growth in output per hour actually decelerated in the second half of the 1990s, falling to 1.0 percent per year for the 1995-99 period, from 1.2 percent during 1989-95 (Table 5). In contrast, the U.S. business sector advanced at an average annual rate of 2.7 percent in the 1995-99 period, up from 1.2 percent in the 1989-95 period (Table 1).

The year 2000 reveals a stronger pattern in terms of output and productivity in the Canadian economy, which outstripped expectations by growing vigorously at an annual rate of 5.0 percent in the first half of 2000, reducing the unemployment rate to its lowest level in nearly a quarter century. During this period, unit labour costs have remained flat in Canada, so the core inflation rate continues to be low and under control, well within the bottom half of the Bank of Canada's target range of 1 to 3 percent. So far, the economy is not

TABLE 5

REAL OUTPUT, LABOUR PRODUCTIVITY AND PRODUCTIVITY ELASTICITY IN THE CANADIAN BUSINESS SECTOR

	INDICES (1992=100)		AVERAGE ANNUAL RATE OF CHANGE		
	REAL OUTPUT	REAL OUTPUT PER HOUR	REAL OUTPUT	REAL OUTPUT PER HOUR	PRODUCTIVITY ELASTICITY*
1949	18.6	29.8	—	—	—
1973	61.8	79.7	—	—	—
1981	80.1	87.8	—	—	—
1989	103.3	96.6	—	—	—
1990	102.7	96.6	-0.57	0.01	-0.02
1991	99.8	97.9	-2.88	1.43	-0.50
1992	100.0	100.0	0.23	2.10	9.13
1993	102.6	101.1	2.56	1.05	0.41
1994	108.4	103.2	5.69	2.17	0.38
1995	110.8	103.7	2.19	0.48	0.22
1996	113.4	103.6	2.35	-0.14	-0.06
1997	119.3	106.1	5.25	2.44	0.46
1998	123.2	106.6	3.27	0.46	0.14
1999	129.1	108.1	4.75	1.39	0.29
	AVERAGE ANNUAL RATE OF GROWTH				
1949-73	—	—	5.13	4.18	0.82
1973-81	—	—	3.30	1.22	0.37
1981-89	—	—	3.23	1.19	0.37
1989-95	—	—	1.17	1.20	1.03
1995-99	—	—	3.90	1.03	0.26

Note: * The productivity elasticity is calculated by dividing productivity growth by output growth.
Source: Statistics Canada, *Aggregate Productivity Measures*, June 2000.

showing any acceleration in the rate of inflation, despite the fact that actual output growth has exceeded projections.

The main difference between Canadian and U.S. productivity growth in the 1990s lies in the performance of the manufacturing sector, with the Canadian sector showing significant relative deterioration. As indicated by the Centre for the Study of Living Standards (CSLS, 1999), the differences in the 1990s are concentrated in the two industry groups involved in the production of computers and computer parts, notably semiconductor manufacturing, computer hardware and telecommunications. It is in these industries where the United States continues to have a productivity edge over Canada. In particular, the fact that high-tech industries are much larger in the United States and constitute such a large portion of U.S. economic output tends to distort the productivity numbers in favour of the United States.

Multifactor Productivity Trends

Multifactor productivity trends for the business, service and manufacturing sectors have recently been estimated by Statistics Canada (Table 6).

In 1999, multifactor productivity in the business sector advanced at an annual rate of 1.5 percent, more than twice the average of the 1988-99, 1979-88 and 1973-79 periods. While this increase fell short of the 2.8 percent growth rate of 1997, it was 1.4 percentage points higher than the 0.1 percent rate of 1998.

TABLE 6

MULTIFACTOR PRODUCTIVITY GROWTH RATES, CANADA
(AVERAGE ANNUAL GROWTH RATE)

	BUSINESS SECTOR	SERVICE SECTOR	MANUFACTURING SECTOR
1961-66	2.9	1.9	4.6
1966-73	2.3	2.3	2.7
1973-79	0.6	0.8	1.7
1979-88	0.4	0.2	1.4
1988-99	0.7	0.2	1.6
1997	2.8	1.9	4.1
1998	0.1	0.6	0.6
1999	1.5	0.8	3.6

Source: Statistics Canada (2000).

In manufacturing, the multifactor productivity gain was also impressive in 1999, reaching an annual rate of 3.6 percent, six times higher than the growth rate of 1998, and at least two percentage points higher than the average growth rate for the 1988-99 and 1973-79 periods. The service sector also experienced a slight increase in multifactor productivity from 1998 to 1999; although considerably less than the growth rate achieved in 1997, it was stronger than that of the 1979-88 and 1988-99 periods.

Overall, productivity growth during the 1988-99 period increased at an average annual rate of 0.7 percent, slightly higher than the average for the two previous periods. Although it is below the average annual increase of 2.3 and 2.9 percent, respectively, for the 1966-73 and 1961-99 periods, it represents an improvement over the 0.6 and 0.4 percent gains made during the 1973-79 and 1979-88 periods.

THE PRODUCTIVITY EXPERIENCE OF THE SERVICE SECTOR

THE PRODUCTIVITY BEHAVIOUR OF THE CANADIAN SERVICE SECTOR differs from that of its southern neighbour. Table 7 breaks down the total economy into different industries. The productivity data presented in this table were constructed by the Centre for the Study of Living Standards, based on Statistics Canada's Labour Force Survey and GDP data.

Services producing industries have not undergone an acceleration in productivity growth between the 1989-95 and 1995-98 periods. A more disaggregated analysis of this sector illustrates that three out of the twelve service industries have experienced at least a one percentage point decrease in labour productivity growth between the two periods. In addition, productivity growth in health and social service industries decelerated by 0.4 percentage points. The average annual growth rate in output per worker in communication and other utility industries decelerated by 1.5 percentage points, in government services by 2.67 percentage points, and most importantly, in business services by 1.5 percentage points. The latter industry has exhibited negative productivity growth rates for both the first and second half of the decade, falling from -1.0 percent per year to -2.5 percent.

However, the data point to substantial gains in productivity in the finance and insurance industries, which experienced an increase in productivity growth of 3.9 percentage points from 1989-95 to 1995-98. In the same way, productivity growth in retail trade accelerated 2.15 percentage points. The figure is higher than the 2.6 percent acceleration in productivity measured for finance, insurance and real estate in the United States between the two periods. The faster productivity growth in accommodation, food and beverage industries, as well as other service industries was also rather impressive in Canada.

TABLE 7
GROWTH RATE OF VALUE ADDED PER WORKER EMPLOYED, CANADA, 1989-98 (ESTIMATES OF GDP PER EMPLOYED WORKER, BY INDUSTRY, IN CONSTANT 1992 DOLLARS)

		Average Compound Growth Rate		
		1989-95	1995-98	(1995-98)-(1989-95)
T001	All Industries	0.94	0.83	-0.11
T008	Goods Producing Industries	1.95	1.30	-0.65
T009	Services Producing Industries	0.67	0.72	0.04
A	Agric. and Related Services Industries	3.13	2.32	-0.80
B	Fishing and Trapping Industries	-4.00	3.90	7.90
C	Logging and Forestry Industries	-5.15	3.43	8.58
D	Mining (incl. Milling), Quarrying and Oil Wells	4.85	3.51	-1.34
E	Manufacturing Industries	2.55	1.14	-1.40
F	Construction Industries	-1.36	2.23	3.59
G	Transportation and Storage Industries	1.64	2.48	0.83
H	Communication and other Utility Ind.	2.28	0.77	-1.52
I	Wholesale Trade Industries	2.01	2.56	0.55
J	Retail Trade Industries	0.52	2.66	2.15
K	Finance and Insurance Industries	2.79	6.68	3.90
L	Real Estate and Insur. Agents Industries	1.32	1.82	0.50
M	Business Services Industries	-1.05	-2.50	-1.45
N	Government Services Industries	2.57	-0.10	-2.67
O	Educational Services Industries	-0.98	-0.75	0.22
P	Health and Social Services Industries	-1.08	-1.51	-0.44
Q	Accommodation, Food and Bev. Serv.	-2.13	0.81	2.95
R	Other Service Industries	-1.53	0.24	1.77

Source: Centre for the Study of Living Standards, based on Statistics Canada Labour Force Survey and GDP Data.

INVESTMENT IN MACHINERY AND EQUIPMENT

FOR THE FIRST HALF OF THE 1990S, machinery and equipment investment was much weaker in Canada than in the United States, and this lacklustre performance failed to produce, with a lag, a revival of service sector productivity in the second half of the 1990s. However, in the second half of the decade, real machinery and equipment investment took off, and thus seems to be highlighting the recent upward push in Canadian productivity figures.

Table 8 provides data on business investment in machinery and equipment in both constant and current dollars. Real investment growth during the 1995-99 period advanced at an astounding 14.3 percent per year, a much higher rate than the 2.1 percent for the 1989-95 period and the 6.6 percent for the 1981-89 period. In the first half of 2000, real investment growth reached a stunning 16 percent annual rate.

Data on business investment in machinery and equipment as a percentage of GDP, in both constant and current dollars, are also presented in Table 8. Canadian firms have also made substantial purchases of information technology products since 1996. In the first half of 2000, real investment in machinery and equipment reached 10.6 percent of GDP, up from 6.4 percent in 1995 and 6.1 percent in 1989.

In the second half of the 1990s, many more businesses have been investing in information technology and in computerizing their operations. According to a Bank of Canada survey covering 140 firms that are broadly representative of the Canadian business sector, 65 percent of Canadian firms invested in these new technologies during the 1990s. This proportion is 50 percent higher than in the previous decade. Undoubtedly, the productivity payoff from this investment will be felt in coming years throughout Canada.

Canadian Productivity Prospects for the Next Decade

THE *NEW ECONOMY* VIEW IS BECOMING increasingly popular among Canadian economic policy makers. Paul Martin, Minister of Finance, said in a recent speech that: "Rapid advances in technology are fundamentally altering our economy and creating the possibility of tremendous new job creation and prosperity." (Finance Canada, 2000)

Then Bank of Canada Governor, Gordon Thiessen, seemed more pessimistic than the Department of Finance about the impact of the *new economy*. The reason is apparent in his statement about the future prospects of the *new economy*: "It is possible that the investment boom we have witnessed in Canada since 1996 will increase productivity growth and capacity more quickly than we are allowing for. There is a good deal of anecdotal evidence that some of the American experience (burgeoning investments in technology leading to robust productivity gains) is being replicated in Canada. Until recently, there had been little evidence of this in our official, economy-wide productivity statistics. But there was a significant gain in productivity in the data for the second quarter of this year released recently." However, he indicated that: "It remains to be seen whether or not this is a trend." (Bank of Canada, 2000)

TABLE 8

BUSINESS INVESTMENT IN MACHINERY AND EQUIPMENT AND TOTAL INVESTMENT IN MACHINERY AND EQUIPMENT, CANADA

	BUSINESS INVESTMENT (MILLIONS OF 1992 DOLLARS)		TOTAL INVESTMENT (PERCENTAGE OF GDP)	
	CONSTANT DOLLARS	CURRENT DOLLARS	CONSTANT DOLLARS	CURRENT DOLLARS
1981	23,588	27,677	4.48	5.36
1982	19,889	25,064	3.93	5.06
1983	19,517	24,361	3.78	4.82
1984	20,830	25,688	3.87	4.93
1985	23,992	28,830	4.21	5.19
1986	26,595	31,918	4.57	5.59
1987	30,696	36,001	5.06	6.03
1988	36,411	41,899	5.71	6.67
1989	39,216	44,942	6.06	7.02
1990	37,476	42,594	5.82	6.66
1991	37,678	38,918	6.05	6.26
1992	38,652	38,652	6.18	6.18
1993	36,858	37,678	5.82	5.94
1994	40,348	42,568	6.03	6.33
1995	44,292	46,486	6.40	6.67
1996	48,561	48,599	6.91	6.81
1997	59,981	60,699	8.08	8.02
1998	65,357	65,618	8.54	8.36
1999	75,557	70,353	9.56	8.60
2000*	87,444	75,910	10.63	—
	AVERAGE ANNUAL GROWTH RATE			
1981-89	6.56	6.25	—	—
1989-95	2.05	0.56	—	—
1995-99	14.28	10.91	—	—
1995-2000	14.57	10.31	—	—

Note: * Annual estimate based on growth rate in the first half of 2000.
Source: Statistics Canada, Cansim database, D15424 and D15457, D15440 and D15410 http://www.statcan.ca/datawarehouse/cansim.cansim.cgi.

Unlike the Federal Reserve Board, the Bank of Canada seems less willing to probe the limits of the NAIRU and push down the unemployment rate until inflation accelerates. The economic growth objective appears to receive lower weight relative to the low inflation objective in the conduct of monetary policy in Canada than in the United States.

In support of the *new economy* view embraced by the Department of Finance and, to a certain degree, the Bank of Canada, a strong case can be made that the *new economy*, characterized by strong trend productivity growth, is finally arriving on this side of the border, triggered by a reversal of most of the factors that have impeded productivity growth in the second half of the 1990s.

- The first of these factors concerns the high technology sector. This sector, although much smaller than in the United States, is now enjoying much faster growth, almost four times the rate for the overall economy (Finance Canada, 2000). There is evidence now that an investment boom in the high technology sector is creating the right conditions for improved productivity that would allow the economy to expand without inflation. Indeed, high-tech industries are fuelling rapid growth in many urban centres such as Ottawa and Kitchener-Waterloo.
- Real machinery and equipment investment in Canada skyrocketed in the second half of the 1990s (Table 8), opening the door to higher productivity payoffs throughout the economy in coming years, in the wake of this investment.
- In addition, the unemployment rate, which remained higher in Canada than in the United States during the 1990s, has given employers less incentive to substitute capital for labour and thwarted the positive productivity effects of a full utilization of resources. However, in the first half of 2000, the unemployment rate fell below 7 percent and it could go significantly lower if economic growth remains robust, which would allow for a more productive use of labour.
- Finally, Statistics Canada is considering the possibility of following the United States lead in the treatment of software expenditures as an investment in the national accounts. Undoubtedly, this would increase both past and future measured productivity growth figures.

We believe that the changes we are witnessing today will continue into the foreseeable future, as supported by the most recent productivity numbers. In our view, the balance of evidence now suggests that Canada's productivity growth (business sector output per hour) could be in the 2.0-2.5 percent per year range over the next decade, if not for the next two decades, which would represent a doubling of the growth rate of the 1980s and 1990s.

What happens in the United States spills over to Canada, although often with a lag. In the past, Canada's productivity growth has tracked or even exceeded U.S. productivity growth as the same forces are at play in the two countries. The factors that have produced an acceleration of measured productivity growth in the United States since 1995 are now beginning to operate in Canada. As noted above, these include the rapid expansion of high-tech industries, strong machinery and equipment investment, low unemployment and changes in statistical methodologies.

CONCLUSION

THIS STUDY HAS SHED LIGHT on the unprecedented resurgence of productivity growth in the United States since 1995.It has also shed some light on the Canadian economy, which has not experienced the productivity miracle of the United States, at least not until very recently.

The proponents of the *new economy* view, defined as higher trend productivity resulting from the spread of information technology, point to faster productivity growth in the business sector, particularly in the service sector, as proof that the U.S. economy is undergoing a fundamental revolution brought about by globalization and technology. Sceptics, on the other hand, argue that due to the onset of diminishing returns, all the benefits of IT have already been realized and the recent U.S. productivity performance could prove to be a temporary phenomenon.

The diffusion of information technology, and in particular the Internet, throughout the economy has clearly some way to go, especially in Canada. Generally, it takes time for revolutionary technologies to move along learning curves and diffusion curves. As businesses restructure their operations, the extensive adoption of information technology could result in further improvements in productivity growth. In Canada, rising IT investments in recent years will result in faster productivity growth over the next decade.

Appropriate economic policy is always important to foster growth, but it becomes even more crucial at times of rapid technological change. The economic landscape has changed, and thus new policy regimes that are more consistent with the *new economy* must be implemented to ensure that our potential productivity gains translate into actual gains.

The concept of the *new economy* is controversial and much debated amongst economists. Who will turn out to be right in the long term? Only time can tell, for not even the best forecasters can provide a definitive answer about the future behaviour of the economy. Until then, let us cherish the miracle that has added more vibrance to our old economic landscape, in the process opening the door to a more efficient and blooming economy.

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APPENDIX

TABLE A1

SOURCES OF GDP PER CAPITA GROWTH IN CANADA AND THE UNITED STATES

	CANADA	UNITED STATES	CANADA–UNITED STATES
		1989-2000	
GDP per Capita	1.32	2.20	-0.88
Output per Worker	1.16	1.88	-0.72
Employment/Total Population	0.16	0.31	-0.16
Working Age Population/Total Population	0.27	0.10	0.17
Employment/Working Age Population	-0.11	0.22	-0.33
		1989-96	
GDP per Capita	0.30	1.43	-1.13
Output per Worker	1.00	1.34	-0.34
Employment/Total Population	-0.69	0.09	-0.78
Working Age Population/Total Population	0.18	0.04	0.14
Employment/Working Age Population	-0.87	0.05	-0.92
		1996-2000	
GDP per Capita	3.13	3.56	-0.43
Output per Worker	1.44	2.83	-1.39
Employment/Total Population	1.67	0.71	0.96
Working Age Population/Total Population	0.43	0.19	0.24
Employment/Working Age Population	1.23	0.51	0.72

Source: Centre for the Study of Living Standards, http://www.csls.ca.

TABLE A2

VALUE ADDED PER EMPLOYED PERSON, GROWTH RATE BY INDUSTRY, UNITED STATES, 1981-99

	AVERAGE COMPOUND GROWTH RATE			
	1981-89	1989-95	1995-99	(1995-99)-(1989-95)
Total Economy	1.38	1.11	1.98	0.87
Private Industries	1.31	1.07	2.38	1.32
Agriculture, Forestry and Fishing	3.60	0.01	5.18	5.17
Farms	4.97	0.45	9.65	9.20
Agricultural Services, Forestry and Fishing	3.22	-0.36	-0.33	0.03
Mining	8.02	4.71	4.00	-0.71
Metal Mining	9.90	8.39	16.45	8.06
Coal Mining	9.84	11.49	11.94	0.45
Oil and Gas Extraction	8.72	3.86	1.89	-1.97
Nonmetallic Minerals, Except Fuels	5.17	2.26	5.39	3.13
Construction	0.64	-0.13	-0.03	0.10
Manufacturing	3.74	3.14	4.41	1.28
Transportation and Public Utilities	2.21	2.59	1.66	-0.93
Transportation	1.91	2.43	1.74	-0.70
Communications	4.31	4.86	2.86	-2.00
Electric, Gas and Sanitary Services	1.67	2.36	2.49	0.13
Wholesale Trade	3.37	2.85	8.19	5.35
Retail Trade	1.61	0.91	5.20	4.29
Finance, Insurance and Real Estate	-0.12	1.64	2.86	1.22
Banking	N/A	2.65	1.35	-1.29
Credit Agencies Other Than Banks	N/A	-1.20	1.48	2.68
Security and Commodity Brokers	2.93	5.11	20.62	15.50
Insurance Carriers	-4.25	1.64	1.06	-0.58
Insurance Agents, Brokers and Services	0.31	-4.43	-0.27	4.16
Real Estate	0.25	1.52	1.57	0.05
Holding and Other Investment Offices	-25.31	7.35	20.73	13.38
Services	-0.16	-0.79	0.28	1.07
Hotels and Other Lodging Places	0.60	1.68	-0.88	-2.56
Personal Services	0.81	-1.40	1.62	3.02
Business Services	N/A	0.81	2.27	1.46
Auto Repair, Services and Parking	-0.74	0.25	0.92	0.67
Miscellaneous Repair Services	0.39	-2.55	-0.80	1.75
Motion Pictures	1.51	-3.09	-0.97	2.12

TABLE A2 (CONT'D)

	Average Compound Growth Rate			
	1981-89	1989-95	1995-99	(1995-99)-(1989-95)
Amusement and Recreation Services	0.95	-0.17	1.89	2.06
Health Services	-1.15	-2.13	-0.92	1.21
Legal Services	-1.83	-0.76	0.60	1.35
Educational Services	0.14	-0.35	-1.92	-1.57
Social Services and Membership Organizations	-1.14	0.60	-2.10	-2.70
Miscellaneous Professional Services	N/A	-1.32	0.41	1.73
Government	0.33	0.28	0.69	0.41
Federal	0.88	1.75	2.05	0.30
State and Local	0.14	0.05	0.57	0.52

Source: Calculated by the Centre for the Study of Living Standards using output and employment data available from the BEA website. Release date: June 2000.

Part VI
Social Aspects of Productivity

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23

Economic and Social Aspects of Productivity: Linkages and Policy Implications

INTRODUCTION

THERE IS A VERY LARGE LITERATURE ON PRODUCTIVITY, most of which has historically focused on the role played by input accumulation, technical change and factors (such as research and development or entrepreneurship) that are traditionally labelled as subject to influence by economic policy. In recent years, however, the discussion of productivity issues has broadened to include consideration of the potential impacts of inequality, social capital, health, education and other societal aspects that have conventionally been viewed as the domain of social policy. Hence, joint consideration of social and economic aspects of productivity is increasingly recognized as important. But since originally the reason for separate consideration of these issues was the complexity of their interactions, joint consideration is far from straightforward.

In this chapter, our task is to review the papers of Harris (2001) and Sharpe (2001), pull together the main findings, integrate the results of other Canadian and international researchers, and identify research gaps in this area. The chapter therefore begins by asking how productivity should be defined, before proceeding to a consideration of Harris' and Sharpe's papers, and then asking: i) What is missing from standard analyses of productivity? and ii) How should one incorporate social concerns in an analysis of productivity?

WHAT IS PRODUCTIVITY?

PRODUCTIVITY IS SOMETIMES DEFINED IN VAGUE, or even circular terms. The *Concise Oxford Dictionary*, for example, defines productivity as: "Capacity to produce; quality or state of being productive; production per unit of effort; effectiveness of productive effort."[1] The *Houghton Mifflin Dictionary* is at least fairly clear about *what* is being produced, defining productivity as "... of or involved in the creation of goods and services to produce wealth or value." A similar focus on goods and services is apparent in the work of Harris (1999, p. 2), who defines productivity as "A measure of how effectively the economy's resources are translated into the production of goods and services." However, Barrell, Mason and Omahony (2000, p. 3) take a more general view: "We would define (productivity) to mean output per unit of productive input."

Leaving aside the frequent use of qualifiers such as *productive* in the definition itself, productivity is certainly about the effectiveness of the process that creates goods and services. However, there is nothing in these definitions that necessarily restricts the idea of output to those goods and services sold in formal markets. And although, in practice, attention is often restricted to marketed goods and services, there is a certain vagueness in many definitions about what is being used up in the process — an imprecision reflected in the continuing controversy over whether labour productivity or multifactor productivity is the appropriate subject of analysis. In the more general definitions, productivity is about the ratio of outputs to inputs. Perhaps because this approach invites questions about what to label as an output and what to consider an input, economic discussions of productivity often restrict attention to outputs that can be exchanged for cash in market transactions — the goods and services counted as part of Gross Domestic Product (GDP). However, even in this case an accurate specification of the inputs used up in production is essential if changes in the level of productivity are to be correctly gauged.

In theoretical discussions of productivity, the assumption is often made that all inputs and outputs of the productive process have market prices that are determined in perfectly competitive markets, without externalities. In this case, the aggregate private and social values of outputs and inputs are identical and can be obtained by summation of the market values of inputs and outputs. However, in the section entitled *Social Issues and the Measurement of Productivity*, we argue that if one is to be concerned with the real world, one must take seriously the possibility that some inputs[2] in the productive process may not have market prices.

In the same section, we return to the distinction between output and inputs of goods and services and of *marketed* goods and services. For now, it suffices to note that Harris and Sharpe differ in their basic conception of what it is that society wants to maximize. Harris focuses solely on GDP and the role that social policy may or may not play in retarding or speeding the rate of growth of GDP per capita. Sharpe, on the other hand, has the idea that policy makers may want to maximize economic well-being, which is a broader concept than GDP per capita.

HARRIS: SOCIAL POLICY AND PRODUCTIVITY GROWTH

WHAT IS THE OVERALL LINK BETWEEN INEQUALITY AND PRODUCTIVITY?

AS HARRIS (2001, p. 5) PUTS IT: "My main conclusion is a non-conclusion." Although there is a long history of arguments about the connection between productivity (in the sense of GDP per capita) and various measures of the extent and outcomes of social policy, the *general* case remains unproven. Some have argued that greater inequality and a diminished role for the welfare state would encourage productivity growth, while others have defended the reverse proposition. In the 1970s, the dominant view in economics was that an equity /efficiency trade-off existed, but in the 1990s it was noticed that, in many cases, more equal societies had higher rates of growth than unequal nations.[3] Since the late 1980s, a variety of theoretical models have been used to explore the arguments in favour of the complementary role of the state in social and economic policy — particularly the endogeneity of economic growth to investments in human capital, when poor parents and imperfect capital markets would otherwise imply an underinvestment in the skills of poor children.[4]

However, it is asking enormously from the data to expect cross-country regressions to resolve this issue with any finality. The data are highly imperfect and the sample size is small. It is not clear what structural process is relevant and how it can be estimated. Theory does not provide a satisfactory guide as to functional form, and non-parametric methods are susceptible to differing interpretations.[5] Even if one could get straight answers to general questions, it is not clear how that would assist decision-making on particular policy issues. Hence, a non-conclusion is quite reasonable.

Authors who want to do an econometric examination of the relationship between inequality, or the welfare state, and an outcome such as GDP growth or productivity must choose a sample of countries and a set of statistics to summarize inequality or the welfare state. In addition, the choices made regarding the estimation technique, functional form, control variables and measures of productivity are important. In practice, inequality statistics are reliable and frequent only for a limited number of high-income countries, and even then rarely extend before 1950. Hence, the only way an econometrician can get a reasonably large data set is to pool together developed and developing countries.

However, it takes some courage to argue that regression results dominated by the measured inequality in countries such as Pakistan or Chad have much relevance for the policy choices of a country like Canada. Not only do we know that the measurement of inequality in developing countries raises a daunting number of statistical problems, but we have good reason to believe that economic development is all about structural and institutional change, and the processes that determine productivity growth are highly likely to change as development occurs.[6] When one restricts attention to the twenty or so OECD countries that do have reliable statistics on the distribution of income over a significant period of time, one is left with very few degrees of freedom to control for the multiplicity of influences on productivity, the varying time lags of their influence, and the reciprocal causation and simultaneity of economic and social processes. As Harris notes, empirical growth regressions are very sensitive to the set of explanatory variables used. Some processes (like tax policy) may have an impact within a few years while others (such as education) influence flows at the margin and only affect the stock of human capital slowly, as new cohorts enter the labour market and older cohorts retire. Correlation is not causation, and one can often tell a story either way — perhaps higher income growth countries buy more nice things like education and income equality, and perhaps more income equality and education enable more rapid growth.

Harris could also have noted that it is not entirely clear whether country fixed effects should be differenced out (as per Forbes, 2000), or whether they are at the heart of the issue. Business cycle effects on both inequality and social spending are also viewed as important, and business cycles are correlated to some degree across some OECD countries, so country/year observations are not independent.

Furthermore, a continuing annoyance to those who have studied economic inequality is the fact that the recent inequality/growth literature has been dominated by macro-econometricians who appear to have no knowledge of the complexity and ambiguity inherent in the measurement of inequality. Although Atkinson's seminal article of 1970 pointed out that differing summary measures of inequality (such as the Gini index, the Theil ratio, coefficients of variation, etc.) emphasize different parts of the distribution of income, and are therefore frequently at odds in the inequality ranking of countries, the subsequent extensive literature on inequality measurement has been largely ignored by macro-econometricians of the growth/inequality genre. In the literature on inequality,[7] a great deal of attention is paid to which income concept is used, the time period over which income flows are calculated, the definition of the recipient unit, and the social welfare and ethical properties of the summary statistics chosen. These measurement issues matter a lot. Country rankings do change, depending on measurement choices.[8] But the current crop of macro types charge on in ignorance.[9]

Moreover, some of the proposed models for the interaction of inequality and growth/productivity are much more relevant for some measures of inequality than others.[10] If the propagation mechanism for the growth/inequality linkage is thought to be the rewards to entrepreneurship or the incentives to private savings, then presumably we would like to focus on differences in income in the middle to upper range of the income distribution. If the issue is the liquidity constraint facing poor families as they invest in childhood human capital, then it is the characteristics of the lower part of the income distribution that matter. In any event, we should use a measure of inequality that has the minimal feature of increasing when income is transferred from poorer to richer individuals (which is not true of the 90/10 ratio).

Measurement of the aggregate size of government is no less problematic. There appears to be an implicit assumption, in many quarters, that the alternative to a large government role (measured by public expenditures as a percentage of GDP) is a smaller role for government in social policy and a greater role for market forces. However, the relevant alternative may be a different *type* of state intervention, rather than no intervention.

In general, government can try to achieve a given objective (in social or economic policy) by direct expenditure, by creating incentives through the tax system, or by regulation. These policy tools are likely to be substitutes, since mandated private provision can replace public provision, and the absence of one type of intervention (e.g. a public pension plan) can increase political pressure for tax expenditures to subsidize alternative mechanisms (such as employer-paid pension plans). Measuring *direct expenditure* on a social policy is therefore measuring a particular policy tool, not measuring social intervention *per se*. *A priori*, it is not clear whether regulation or tax expenditures will generally have a lower efficiency cost than direct expenditure. If the alternative to public delivery of, for example, health care services is tax expenditures and regulation, a smaller share of direct expenditure for the state may be accompanied by higher levels of state intervention in other ways, and these other policy intervention modes will have their own effects on the efficiency of aggregate outcomes.

To take the example of the United States, the government is involved in the health care system in a variety of ways — paying directly for the provision of health care to senior citizens and social assistance recipients through MediCare and MedicAid, providing support through the tax system to employer-sponsored health insurance plans, and governing the provision of health care by regulating health care insurers, Health Maintenance Organizations (HMO) and hospitals. As problems with health care delivery (e.g. with HMO) have proliferated, regulations and legislation have been suggested in response. Arguably, the regulation of health care insurers and providers has the most direct impact on the practice of medicine, and tax expenditures on health care insurance are larger than the direct budgetary cost. However, although all these initiatives are driven by the politics of health policy in the United States, neither the costs of tax expenditures nor the burden of regulation are included in most measures of the size of the U.S. social policy effort — and it is hard to argue that the system as a whole is either more efficient or more equitable than a direct expenditure system.

Finally, cross-country evidence cannot be thought of as representing entirely independent policy experiments. The nations of Europe have been gradually converging toward a common legal and institutional framework over the past forty years. One of the express purposes of organizations such as the OECD is to facilitate learning from policy lessons across countries — and whether or not they are true lessons, OECD initiatives such as the 1995 Jobs Study attempt to disseminate a common policy message. To the extent that international policy coordination is successful, this has the effect of reducing cross-country policy differences.

In the productivity literature, there are often heated debates about the appropriate measure of productivity. The relatively small degree of identifying variation in OECD data, the alternative possibilities for potential dependent variables, the very imperfectly measured independent variables, and the small sample of observations all conspire to frustrate macro-econometricians who try to find a robust link between productivity and inequality or social policy.

However, it is not entirely clear what would be the pragmatic use of a general finding, even if it were robust. Although one can agree that it would be useful to ideologues of both the left and the right to find a general relationship congenial to their own point of view, pragmatic policy makers know that a *general* econometric relationship is not very useful for any *particular* issue. To estimate econometric relationships, one has to use data from the past, and if it is believed that a paradigm shift in production technology is under way, then past data is not necessarily of much use in predicting the impact of future policy choices.

In the last section of his paper, Harris explores the implications of the *new economy* for inequality, growth and productivity. He argues that the computer and telecommunications revolution is an example of a new general purpose technology (GPT) and that, in recent decades, trends in productivity growth and inequality have been driven by the transition process of adjustment to the new technology. He distinguishes between the growing pains associated with transition and the steady state outcomes of the new technology, which will be increasingly dominant as the technology becomes embedded.

However, sceptics have questioned each major element of this story. The assertion that there has been a *general* increase in inequality in capitalist countries has been contested by Atkinson (1998), Brandolini (1998) and Osberg (2000), among others. Everyone agrees that the United States and the United Kingdom have experienced greater inequality since about 1980, but other nations display a diversity of experience — which casts some doubt on the generality of a technology-driven story. Although Harris accepts the argument that skill-biased technical change has been an important element in the rising U.S. inequality, that argument has been severely criticized by Handel (2000a,b) and Howell (2000). On the issue of whether or not a new age of high-productivity growth is at hand, Gordon (2000) has been a prominent sceptic. He emphasized the importance of measuring quality change in computers and telecommunications for disentangling the trends in real output growth in that sector, which has dominated the increase in overall productivity growth. If the sceptics are right, there has been no structural break in the determinants of productivity and inequality, and macro-econometric results based on data from earlier periods retain their validity.

However, if the *new economy* story is correct, then estimates of the relationship between inequality, social policy and productivity in the *old economy* era are primarily of interest to economic historians. Social commentators either on the left or on the right of the political spectrum are then free to make whatever conjectures seem plausible as forecasts of the relationship between inequality, social policy and productivity, and any errors in such forecasts cannot be disproved for several years hence.

But even if we were to find a general relationship to suit either a leftist or a rightist predilection, what would we do with it? Unless ideology were to be the determining factor in policy choices, one would still have to look at the costs and benefits of specific policies. Harris concludes by arguing that the justification of any particular social policy must rest on the cost-effectiveness with which it can achieve its stated social goals. However, in an important sense, *that would be true whatever the general relationship, or lack thereof, found in cross-country macro data.*[11]

WHICH POLICIES ARE LIKELY TO INCREASE PRODUCTIVITY MOST?

HARRIS ARGUES THAT:

> The policies which have been proven to most likely increase productivity are those which focus on the proximate economic levers of productivity growth, i.e. those that stimulate investment and innovation, promote competition, and facilitate the international diffusion of knowledge.
> (Harris, 2001, p. 49)

This conclusion appears reasonable and plausible enough on first reading, but it fits poorly with Harris' fourth conclusion that the *new economy* perspective provides a coherent explanation based on accelerating technological change. If it is really the case that GPTs create new, more productive patterns of work organization that are structurally different from the *old economy* being replaced, then macro-econometric regressions using historic data on which this conclusion is based may not predict particularly well *new economy* relationships.

It is at least arguable that the autonomous work group in a flat organizational structure is an form of organization particularly suited to the distributed processing of knowledge, and that this type of *Internet age* organization depends heavily on human capital formation, social cohesion and minimal inequality within work groups. If so, it is unclear whether such historically important issues as capital formation will retain their primacy. Although concepts such as social cohesion or social capital are difficult to measure clearly, the fact that it is difficult to prove empirically their important influence on productivity does not necessarily imply that they are insignificant.

PRODUCTIVITY AND EDUCATION

THE CONCLUSION DRAWN HERE IS THAT:

> The one social policy for which there is ample evidence demonstrating positive productivity effects is education. A substantial portion of Canadian economic growth appears to be attributable to the high levels of educational attainment in Canada.
> (Harris, 2001, p. 49)

This conclusion seems a bit harsh, since the evidence from health economics is also very strong. But the basic point made is that evidence on the positive impacts of education comes from both macro-econometric cross-country and time-series regressions *and* from a very large body of micro-econometric evidence. Indeed, that evidence is stronger than Harris makes out. He could have referred to some impressive evidence on the externalities of education to buttress his conclusion that a public role in the financing of education is desirable.

Like much of the economics literature, Harris focuses on the monetary returns to education for individuals. Certainly this is an important point for productivity, if measured narrowly in terms of marketed output — and there is very strong evidence that education directly yields a significant private and social rate of financial return. (Harris summarizes the micro evidence by indicating a rate of return of 8 percent at the median of estimates, while the macro impact of an additional year of schooling would be a 6 percent increase in per capita output.)

However, education also affects many other facets of behaviour. Because the number of years of schooling is a variable recorded in almost all micro data sets, researchers in economics, politics and sociology routinely include it as a regressor (often, education is not the main focus of interest, but even if the intention is to examine something else while controlling for education, the coefficient on the years of schooling is a valid estimate). People with more education have better health outcomes, smoke less, buckle their seat belts more often, are less likely to be involved in criminal activity, are more effective consumers, exhibit less prejudiced attitudes toward members of other ethnic or racial groups, are more likely to vote, are less likely to have children out of wedlock, or to have children who have children while unmarried, give more to charity, are less likely to rely on social assistance — to name only a few (see Wolfe and Haveman, 2000, for a partial listing). In every instance that we are aware of, the behavioural difference associated with education is in the right direction, but it is notable that the benefits of this behavioural change accrue to others in many cases.

In a recent paper, Wolfe and Haveman (2000) have assembled estimates of the behavioural effects of education. By comparing the size of the education effect with the impact of purchased inputs, they have estimated the shadow value of the impact of education on behaviour. They come to the conclusion that "... a conservative estimate of the value of non-labour market influences is of the same order of magnitude as estimates of the annual market earnings-based effects of one more year of schooling." (2000, p. 14)

The conclusion that the social rate of return to education is approximately twice the private return (in the form of increased earnings) is rather important for policy purposes. Historically, the case for public financing of education rested on two main pillars. The equality-of-opportunity argument has both an equity dimension and an efficiency dimension, since social output will rise if poor children are enabled to reach their potential (Osberg, 1995). The social insurance risk-pooling perspective recognized that when human capital investments represent undiversifiable risk for each person, risk-averse individuals who bear the full cost will underinvest, but a society with progressive income taxation and public education shares in both the costs and returns of individually uncertain investments, and has higher incomes on average. Wolfe and Haveman's quantification of the externality benefits of education in the form of better behaviour adds a third important reason for public funding, since the benefits of more education they mention in their study (and others they could not quantify) accrue to the public at large.

For the analysis of productivity, one can note that these external effects of education will have an impact on measured growth performance, but that in the conventional mode of estimation it will typically be captured as greater productivity or faster growth of other factors of production. If, for example, additional years of education reduce the probability of criminal activity, GDP growth will be faster since more people will be working rather than spending time in jail, and more capital will be available for investment as enforcement, crime avoidance and incarceration activities absorb fewer resources. However, the background role played by education will not be apparent.

In short, the positive role played by education is understated in Harris' paper.

THE *NEW* ECONOMY

HARRIS CONCLUDES THAT:

> The *new economy* perspective provides a coherent explanation of both recent growth and inequality trends as endogenous reactions to a common cause — the acceleration of technological change.

As noted earlier, each facet of the *new economy* story has been contested, and it remains an important but unproven hypothesis. Although arguing for this approach, Harris does note that since the hypothesis is that we are in the middle of a period of change toward a new set of GPTs, it is in the nature of the event that we will not know for sure until the transition process has occurred.

However, it is not clear what direct implications for social policy flow from the *new economy* scenario, other than a general predilection toward a greater importance of human and social capital.

THE LINK BETWEEN ECONOMIC WELL-BEING AND PRODUCTIVITY

THIS SECTION EXAMINES SHARPE'S DISCUSSION of the relationship between economic well-being and productivity. Sharpe uses the *Index of Economic Well-being* (Osberg and Sharpe, 1998; Osberg, 1985) as a framework for his discussion. As he notes:

> The four components or dimensions of economic well-being in the Index of economic well-being developed by the Centre for the Study of Living Standards are the following:
>
> - Effective per capita flows of consumption that include consumption of marketed goods and services, and effective per capita flows of household production, leisure and other unmarketed goods and services;
> - Net societal accumulation of stocks of productive resources, including net accumulation of tangible capital, housing and consumer durables, net accumulation of human capital and R&D capital, net changes in the value of natural resources stocks, the cost of environmental degradation, and net change in the level of foreign indebtedness;

- Poverty and inequality, including the intensity of poverty (incidence and depth) and inequality of income; and
- Economic insecurity from job loss and unemployment, illness, family break-up, and poverty in old age.

In this perspective, the aggregate economic well-being derived from a given stock of wealth and flow of consumption of goods and services depends partly on how the current consumption of goods and services is distributed and partly on how insecure individuals are in anticipating their future income flows. However, productivity is an aggregate concept. More precisely, *productivity* is a concept that refers only to *aggregate* ratios — the ratio of outputs to inputs. If the objective is to maximize economic well-being, then presumably one would think of *outputs* as whatever increases in economic well-being, and *inputs* as whatever sacrifices of well-being are necessary for production. If we adopt this perspective, then a wide range of social policy initiatives will affect productivity since they affect inequality and insecurity.

However, we noted in the first section that, typically, productivity is more narrowly defined — in general terms, as the ratio between the aggregate value of *goods and services* produced and the aggregate value of *goods and services* used as inputs in that production. If we use the term productivity in this sense, then its analysis becomes not only easier (because it relies solely on easily measured magnitudes) but less important (because these easily measured magnitudes may not be what people care all that much about). In the narrow definition of the issue, inequality and insecurity can then affect productivity only to the extent that they affect aggregate goods and services, either in a measurement sense or in actual outcomes.

In the section entitled *What Is Productivity?*, we argue that if specific factors affect the level of output of goods and services produced, it is often useful to think of the issue in terms of inputs to the production process, even if these inputs do not now have market prices. (For example, if low-trust societies have to write complex legal documents to guard against possible fraud in any minor economic transaction, the labour and capital used to create such documents will be subtracted from the net output of desirable commodities. In this case, one could think of social capital as an unpriced input in the production process.) Accurate measurement of productivity should include consideration of all the costs of production of goods and services, both priced and unpriced.

If all costs are counted, improving productivity levels would necessarily increase the aggregate value of resources produced in any given period, which could then be divided between current consumption and accumulation in whatever proportion deemed desirable by the current generation of decision-makers. Improving productivity does not, however, guarantee that current output is divided in optimal proportions between consumption and accumulation[12]

— indeed, if a change in working relationships or technology produces a sufficiently large change in the consumption-accumulation ratio, it is quite conceivable that it might outweigh any productivity gain.

Clearly, incorrect measurement of productivity means that we can no longer be nearly as sanguine about the relationship between productivity and aggregate consumption and accumulation. Measuring labour productivity alone has long been criticized on the grounds that it ignores the influence of both physical and natural capital. It is easy to construct models in which labour productivity rises with the accumulation of physical capital, but consumption (and well-being) decline with the depletion of natural capital, if the price mechanism for natural and environmental resources is deficient. Comparison of the virtues of multifactor productivity and labour productivity is a special (extreme) case of the more general case for including measures of all productive inputs. In the analysis of multifactor productivity, when only a subset of actual inputs is considered in the measure of productivity, there is no guarantee that trends in economic well-being, measured productivity and actual productivity will coincide.

As Sharpe (2001, pp. 2-3) correctly notes, increasing productivity (in the sense of GDP accounting conventions) is a key determinant of trends in marketed per capita consumption — both private and public — which is an important part of total consumption, and therefore of economic well-being. However, Sharpe raises some issues in his discussion of the impact on well-being of productivity improvements in unpaid work that I think are misleading. In principle, technological change certainly affects the value of output of each hour of time spent in unpaid labour. Of course, technological change will affect *both* the market wage and non-market productivity. Since, at the margin, individuals may trade off market and non-market uses of time and can be expected to equalize marginal returns from different uses of time, the issue is how to value each hour of non-market work performed (or leisure enjoyed). By using the opportunity cost of time (i.e. the net after-tax wage for market work) as the shadow price of hours on unpaid labour (or leisure), one implicitly accounts for productivity change in unpaid labour.

On a number of specific issues that are addressed in the calculation of the Index of economic well-being (e.g. the underground economy, average household size, life expectancy), Sharpe points out that there is no clear prediction on the impact of greater measured market productivity. Regrettables like pollution or crime are, however, examples of unpriced inputs in the production of market goods and services. Expenditure on pollution abatement or crime suppression are, in the narrow GDP accounting sense, an increase in input costs with no increase in marketed output (see below however). Hence, a decrease in these efforts results in an increase in GDP per capita, even if that corresponds to a decrease in economic well-being.

Social Issues and the Measurement of Productivity

Economists like to think of productivity as an issue that is separable from the arbitrary institutional differences observed in different societies. In principle, economists would like to have measures of productivity that reflect differences in the technical relations of production, not differences in institutional or legal arrangements. Whether or not a particular production process is judged highly productive should not, in principle, be dictated by whether or not inputs entering its production are priced in the market.

However, the fact that the boundary between market and non-market transactions depends on the institutional structure of society injects an unavoidable interaction between social issues and the measurement of productivity. At one level, the institutional context may only affect the measured productivity of private industry. If, for example, meat packing firms in one country have to hire quality control inspectors, while in another country food standards inspectors in meat packing plants are government employees, the lower labour requirements (either measured as employees per unit of output, or as paid hours per unit of output) of firms in the latter country is a misleading indicator of labour productivity (at the firm level) in the meat packing industry.

More generally, whether or not labour services are priced depends on the institutional boundary between market relationships and services provided by government and the household sector. As already noted in the section entitled *What is the Overall Link Between Inequality and Productivity?*, societies can generally choose among public policy alternatives that involve either regulation or public expenditure, or they can even choose non involvement. Table 1 illustrates how three possible institutional arrangements for child care might affect measured productivity. It compares the scenarios of private provision within the family using unpriced labour, private provision at the work site (if legislation or regulation establishes day care as an employer responsibility), and public sector provision. If both the latter alternatives use day care workers, who are paid less than factory workers, output per employee will fall in either of the last two scenarios, even though aggregate output rises.

This example has been constructed so that the impact on total GDP per worker is the same under either formal daycare alternative scenario — but the impact on measured private sector productivity depends on whether regulation or direct public provision is chosen (even though scenarios B and C are identical in actual technical productivity). However, the main point of the example

TABLE 1

PRODUCTIVITY – OUTPUT AND EMPLOYMENT IN ALTERNATIVE CHILD CARE SCENARIOS

Scenario	Factory	On-site Daycare	Public Sector Daycare	Family Labour	Labour Productivity Value of Output/Paid Employees: Private Sector	Labour Productivity Value of Output/Paid Employees: Market Sector
A	$10,000 10 workers			$0 10 workers	1,000	1,000
B	$15,000 15 workers	$3,000 5 workers		$0 0 workers	900	900
C	$15,000 15 workers		$3,000 5 workers	$0 0 workers	1,000	900

Assumptions: 10 Families – 2 parents, 2 children.
Factory workers earn $1,000.
Daycare workers earn $600.
4:1 ratio in daycare implies daycare frees up 5 workers for factory.

Scenarios: A=Family childcare; B=Firms required by law to provide daycare; C=Public daycare.

is to illustrate how GDP per capita may move in a different direction to GDP per employed worker, when the institutional boundary between market and non-market activity changes.

In general, the number of employees (and measures of labour productivity derived from it) depends crucially on institutional structure — implying that changes in institutional structure will influence the trend in labour productivity growth. It is clear that over the last thirty years, the changing role of women in paid work and household production has been one of the most profound transformations in Canadian society. When half of the country's population changes its mix of daily activities from activities that are unmeasured in GDP to measured activities, we have to expect a substantial impact on the measured trends of marketed output productivity. Since changes in the paid labour force participation of women have not been similar in all OECD countries, the comparison of market productivity trends will depend partly on the relative differences in institutional change.

However, in principle we would like to have measures of labour productivity that are not artefacts of the institutional structure. An accurate measure of labour productivity would not, for example, be affected if the system of wage labour in a capitalist economy were replaced by slavery. In a slave society, workers do not get wages and the stream of current labour services does not generally have a market price.[13] As a consequence, labour usage is therefore not reflected in the variable monetary cost of production. However, the fact that some labour input is unpriced should not, in principle, affect measures of labour productivity.

The deficiencies of relying on output per employee or output per paid working hour as a measure of productivity have been much rehearsed in the literature on multifactor productivity. Measured multifactor productivity growth is a residual, after accounting for the impact on output of changes in specifically considered inputs, and it is clear that the stock of machinery and equipment generates a stream of services that we should measure as an input. A surge in output today, at the cost of neglected maintenance and a depleted capital stock tomorrow, is widely recognized as an inaccurate indicator of productivity.

However, although changes in the stock of purchased machinery and equipment can be estimated with the aid of (contentious) estimates of service life and market depreciation, there are a number of other stocks whose level is affected by the production process. Furthermore, plant and equipment is not the only stock whose level determines the level of output obtained. Whether or not these stocks have market prices depends, again, on the (possibly) arbitrary nature of a nation's institutional and legal structures.

Accurate estimation of productivity trends should, in general, account for unpriced inputs used up in production, and should not be sensitive to institutional changes that affect whether or not productive inputs have market prices. In the analysis of multifactor productivity, for example, the measured productivity of the resource sector should, in principle, reflect its effectiveness in the use of natural resource stocks. In Canada's resource industries, there are many anecdotes of past wasteful production practices that made economic sense only because firms had to pay for labour and machinery, but not for the impacts of these practices on natural resource stocks. Such production practices are not reasonably considered examples of greater productivity.[14] Measures of sectoral productivity should not depend on the proportion of the resource stock that is private, or on the mode of public sector taxation and royalty collection on natural resources.

The definitions of productivity cited earlier do not limit their conception of input to the category of purchased inputs. Hence, accurate measures of productivity should not depend on the pricing mechanism in place for the use of environmental assets. Whether a firm has to pay for a pollution permit, or releases its exhaust gases into the atmosphere at no cost, should not affect its measured level of technical productivity. A full measure of multifactor productivity should count environmental assets used in production, irrespective of the institutional mechanisms that determine whether or not firms have to pay a market price for the depletion of these assets.

In the section entitled *The Link Between Economic Well-being and Productivity*, we reviewed Sharpe's discussion of the impacts of rising productivity levels on economic well-being. That section relied on the discussion in Osberg and Sharpe (1998, 2000) of trends in economic well-being as a weighted average of trends in average consumption, aggregate accumulation, income distribution and economic insecurity. The measure of trends in the various components of economic well-being attempts to be comprehensive in nature. Aggregate accumulation, for example, is thought of as encompassing the accumulation of human capital stocks, as well as net changes in the value of plant and equipment, and changes in consumption per capita are defined to include the value of increases or decreases in leisure, as well as the consumption of market goods.

For purposes of analyzing productivity, the issue is whether an exact measure of the costs of production of goods and services should consider costs incurred along all four dimensions of economic well-being, whether accurately priced in economic markets, or not. The production of goods and services has implications for all four dimensions of economic well-being, all of which could legitimately be considered costs of production, but only some of which are priced (depending on the institutional structure).

Thus, accumulation for the benefit of future generations can occur either in the form of produced capital in machinery, equipment and structures (which are typically priced in capital markets), or in the form of changing levels of natural resource stocks (which are imperfectly priced) or in changing levels of environmental degradation (generally unpriced). An accurate measure of multifactor productivity should account for all resources employed in the current production of goods and services which could have been passed to future generations for their benefit. The Index of economic well-being attempts to be comprehensive in its assessment of aggregate accumulation over time, regardless of whether the underlying assets are priced in the market.

The costs of changes in inequality and insecurity can also be seen as unpriced inputs to the production process, in both a direct and an indirect sense. In a direct sense, the risk of loss of an asset is a cost of many production processes, so in principle we would want the costs associated with a change that increases risk to be reflected in productivity measures, regardless of the allocation of the costs of that risk. For example, if a firm adopts a production process that carries a higher risk of fire, it may decide to self-insure or to buy insurance against loss. Either way, the greater probability of loss is an economic cost associated with that production process — whether borne by firms in the industry or offloaded to the insurance sector.[15]

As well, one could imagine a change in workplace technology that implies both an increase of 10 percent in output per able-bodied employee and a 5 percent probability of permanently-disabling workplace injury. It is possible to imagine an institutional structure in which conventional productivity statistics fully capture both the benefits and costs of this change in technology — i.e. if firms were legally prevented from discharging disabled workers, so that both disabled and healthy workers continue to be booked against that technology. However, this is not the way things are done in Canada and, generally, the institutional structure of a society will determine the allocation of costs — whether disabled workers can be discharged without compensation, whether they can purchase insurance or receive compensating differentials in the form of higher wages for the greater *ex ante* risk, or else. Each of these institutional arrangements has different implications for the share of total injury costs borne by firms, either *ex ante* or *ex post*. The costs borne by workers will be reflected by a change in the observed income distribution, and in the insecurity experienced by workers about their future income stream.

In the workplace injury example, technological change increases the aggregate level of risk, but generally the impacts of a change in the aggregate level of risk and the allocation of the existing level of risk among individuals are often mingled. For example, changes in production processes that reallocate labour often have the effect of changing the value of human capital stocks. To the extent that these changes simply reallocate the returns to human capital between different individuals with different types of human capital, the effect is redistributional (among workers).[16]

However, the issue stressed here deals with the cost of changes in the aggregate level of human capital risk. If technological and institutional changes were to increase the degree of churning that goes on in the labour market, but there was no increase in mean income, the utility level of risk-averse workers would fall. The same amount of output would be produced, but at the cost of an increase in the inequality and insecurity experienced by individual workers — a cost that is not necessarily priced in the market. To the extent that this cost is borne by households rather than firms, it will be unrecognized in productivity statistics.

If technological changes increase the risk of unemployment due to layoff, or decrease the extent and credibility of guarantees of employment continuity, their costs are borne by workers. To the extent that firms have to pay severance, or to keep employees and invest in their retraining, these costs are borne by firms. Either way, there is a real cost to changes in the production process that is being borne by some economic agents — but in the latter case, one can at least expect that firms will consider these costs in making their technology decisions. To the extent that firms have to internalize the human capital impacts of their decisions, one will be more likely to observe actual changes that reflect social costs — but in general, if such costs occur they ought to be considered in analyzing whether such changes improve productivity. Depending on the allocation of costs between workers and firms, one will observe different patterns of *ex post* inequality and poverty outcomes and *ex ante* insecurities about the future. However, these changes in inequality and insecurity outcomes are unpriced consequences of the change in production process — unrecognized costs that should be reflected in productivity measures.

As well, changes in inequality and insecurity can be seen as having an indirect impact, in the sense that trends in their levels can be seen as affecting stocks. Although variously labelled in the literature as *industrial relations climate*, *workplace culture*, *social capital* or *social cohesion*, there is a common perception in a number of disciplines that *something* inherited from the past influences the general level of morale, innovative behaviour, work effort, propensity to strike, likelihood of theft, desire to satisfy customers, willingness to cooperate with other workers, etc. of individual workers. Whatever label one affixes, it is clear that no firm pays a market price for the services of the general level of this input, although its level does affect the amount of output that can actually be obtained from any given amount of capital and number of workers.

It is clear that in workplaces, people tend to watch how other people behave, and adjust accordingly — hence norms of behaviour in workplace culture are very important to individual behaviour. Furthermore, although very important to firm productivity, these aspects of worker behaviour are notoriously hard to measure and to reward at the individual level (*incentivize* in the current jargon). Although the *potential* productive capability of individuals may depend on the skill set enabled by their education, health status and on-the-job experience, what individuals *could* do is generally different from what they *actually* do. If the level of output depends on workplace culture, or social capital or the industrial relations climate, measurements of productivity trends that ignore the cost of unpriced changes in these stocks will be misleading.

Impact of Social Capital on Productivity

AMARTYA SEN HAS ARGUED that technology is often considered in highly restricted terms, for example, as particular mechanical, chemical or biological processes used in making one good or another. The extremely narrow view of technology that emerges from such a limited outlook does little justice to the social content of technology or what Marx called *combining together* various processes into a social whole.[17] The making of things involves not merely the relationship between, say, raw materials and final products, but also the social organization that permits the use of specific techniques of production in factories or workshops or on land. (1990, p. 128)

In much of economic theory, the household side of the economy is modelled as a set of isolated utility-maximizing individuals who care only about their private consumption of market goods and services. Firms are modelled as black boxes that absorb as inputs the labour and capital supplied by individuals and somehow generate market goods and services as output. Economic modelling often dismisses as too complex the twin facts that individuals (including economists) also care about other issues, and that firms need managers because the social relations that maximize the effectiveness of the production process are not inherently obvious.

However, there is a growing literature stressing the importance of social relations surrounding production. Why have social capital and social cohesion become such hot topics in economics in recent years? Neither term fits the normal economics mold. Economics is a discipline that prides itself on precision, but both ideas are hard to define, and often confused with each other. Economists usually start from the perspective of a selfish, utility-maximizing individual, whose interaction with others is limited to buying and selling in the marketplace — yet social capital and social cohesion are both about *social* relationships, *group* identity, and the non-market dimensions of life. Nonetheless, the rising concern with social capital and social cohesion is unmistakable.[18]

In part, the impetus for the growing attention paid to social capital and cohesion has undoubtedly come from events in Eastern Europe. When the Berlin Wall fell in 1989, there was a great deal of optimism among economists about the economic prospects of Eastern Europe. Although, in retrospect, that optimism makes for embarrassing reading, at the time it was thought that economic growth would be rapid in the post-Soviet era. Because Eastern European nations had technically-sophisticated, highly-educated labour forces and a great deal of capital, many analysts expected that the elimination of the dead hand of communist central planning would unleash the pent up potential of Eastern European nations for rapid growth. These expectations were based on the simple notion that economic production occurs when capital, labour and human capital are combined in the workplace. Since many economists thought (and continue to think) that the price signals of an unregulated market are the most effective way of coordinating economic activities, they concluded that as soon as Eastern Europe acquired a market system, good things would happen. And if this was all there was to it, history would have turned out differently.

During the 1990s, the decline in living standards that has occurred in these nations and the rise of gangster capitalism in much of the old Soviet bloc have lead many to ask what went wrong. There is a new recognition of the importance of the social context surrounding market processes. As Sen put it: "Although capitalism is often seen as an arrangement that works only on the basis of the greed of everyone, the efficient working of the capitalist economy is, in fact, dependent on powerful systems of values and norms. Indeed, to see capitalism as nothing other than a system based on a conglomeration of greedy behaviour is to underestimate vastly the ethics of capitalism, which has richly contributed to its redoubtable achievements." (1999, p. 262)

Social capital and *social cohesion* may be new jargon, and events in Eastern Europe may have recently boosted the popularity of these concepts, but they are not really new in social sciences. Within Western nations, there is a long history of concern with the social framework of market processes. Adam Smith noted in the *Theory of Moral Sentiments*, ch. V[19] (1986, pp. 110-12):

> The regard to those general rules of conduct, is what is generally called a sense of duty, a principle of the greatest consequence in human life, and the only principle by which the bulk of mankind are capable of directing their actions. Upon the tolerable observance of these duties depends the very existence of human society, which would crumble into nothing if mankind were not generally impressed with a reverence for these important rules of conduct.[20]

Thus, there has long been a concern in Western nations about the issues raised by the social capital and social cohesion literature, even if early writings tended to be broader in focus, and less quantitative in nature, than the modern social science tradition. Although much of the concern with social capital is motivated by larger political and *quality of life* issues, one can also expect impacts on productivity, narrowly conceived as the ratio of output to inputs.

The desired outputs of the social system can be thought of as a set of strict subsets. Economic well-being is a strict subset of well-being, because however ambiguous the distinction is between social and economic issues, some things cannot be labelled as economic under any reasonable definition of *economic*. The set of issues that individuals care deeply about, and that contribute to their well-being, is broader than the set of economic issues.

However, economic well-being also involves a broader set of issues than the production and consumption of marketed goods and services. Since the distribution of income, insecurity and accumulation for the benefit of future generations also affect the economic well-being of individuals, but are not captured in GDP measures, they represent a larger concept than the latter. Finally, the set of goods and services produced for the market include some expenditures (e.g. commuting to work) that do not contribute directly to economic well-being.

Different forms of capital affect well-being, economic well-being and GDP. Physical capital in plant, equipment and inventory is now well measured in conventional national income accounting and routinely included in estimates of multifactor productivity levels. It has already been argued in this paper that the services generated by natural capital, although often unpriced in economic markets, should be included in assessments of productivity trends.

How should productivity measures recognize the role of the human element in production? By some criteria, one would include measures of health as an element of human capital, since both cognitive and physical skills (whether produced by education or on-the-job training) and health status are specific characteristics of individuals.[21] Both health and human capital are clearly important to labour quality, and hence to productivity, even in its narrowest sense.

Many now argue that social capital represents an important part of productive wealth (World Bank, 1997). There is a vigorous debate about how best to define social capital, but for our purposes let us refer to it as norms and networks that facilitate collective action. In the recent literature, Knack and Keefer (1997) provide an example of studies suggesting that measures of trust could be seen as a useful operationalization of the concept of social capital originally proposed by Putnam (1993). Social capital is a characteristic of communities, and can be expected to increase productivity by broadening the range of transactions that people can engage in with confidence, and also by decreasing the transaction costs associated with trade. For example, if people can credibly trust other market participants, they can expend less resources on lawyers, pay for fewer anti-theft measures, and obtain credit more easily. Knack and Keefer find that measures of social capital are positively correlated with the rate of economic growth.

Organizational capital can be seen as somewhat distinct, in the sense that it is specific to particular organizations such as firms, governments, etc. rather than to society as a whole. But the importance for productivity of expectations and patterns of behaviour within organizations built up from the past is apparent to any real-world manager. Indeed, case studies have shown that the soft technology of workplace organization and motivation is the major focus of many real-world managers, because it is so crucial to realized productivity at the firm level (Osberg, Wien and Grude, 1995). Institutions and social arrangements can be separately identified in order to highlight the importance of formal structures, as well as the more informal norms and networks already discussed. A large part of the problems of transition economies has been traced to the sorry state of their institutions (such as the police and judiciary) and their social arrangements (such as unemployment insurance and medicare). Poorly functioning institutions mean that individuals and firms have to develop alternate arrangements (like private security guards) whose costs often appear in productivity measures. Institutions and social arrangements constitute the framework within which people individually acquire productive characteristics such as human capital. This framework also conditions the interactions of individuals within organizations and the broader community.

All this may be very well, but the sceptical reader in entitled to ask: How much does all this matter in a country like Canada? Hazledine's analysis of the failure of the New Zealand policy experiment is instructive in this regard. As he notes, the adoption of widespread structural reforms in New Zealand during 1984-91 has been followed by a period in which "Macroeconomic performance in nearly all measurable dimensions — GDP and productivity growth, unemployment, income distribution, balance of payments — has been worse than in the previous period in New Zealand and in Australia since 1984" (2000, p. 2). His explanation of the adverse macro trends is that whatever the efficiency gains produced by microeconomic reforms, they were more than compensated by a substantial increase in the proportion of the workforce employed in managerial jobs to supervise more closely an increasingly less cooperative workforce. By his argument, the social impacts of economic reforms — in a country not so very different from Canada — may be large enough to overwhelm any narrowly-defined economic impact on productivity.

CONCLUSION

THIS CHAPTER HAS ARGUED, along with much of the emerging literature on *social capital*, that production processes occur within a social context, whose characteristics heavily influence the amount of labour and capital directly required to produce a given amount of goods and services. One way of thinking about the social framework of economically productive activity is to conceptualize a number of stock variables, whose level influences the level of goods and services production that is possible. From this angle, one can see these stocks as unpriced inputs to the productive process — changes that are an unrecognized cost of decisions about production technologies and social institutions. The priority for future productivity analysis is to more accurately identify and measure these stocks, and their importance for the level of production of goods and services.

ENDNOTES

1 *Concise Oxford Dictionary of Current English*, 6th Edition, Clarendon Press, Oxford University Press, 1976.

2 By input we mean any variable whose level affects the level of output of goods and services (which may be marketed or unmarketed).

3 Osberg (1995) and Benabou (1996) survey this literature.

4 Early papers were Galor and Zeira (1993); Banerjee and Newman (1994); and Benabou (1994).

5 For example, Banerjee and Duflo (2000) interpret the data as indicating that changes in inequality can affect growth, but that the level effect of inequality is hard to determine precisely.

6 Conditional convergence in technology is an example of changing structure, but the classics of growth theory (such as Kuznets, 1966) had broader processes of structural transformation in mind.

7 See Osberg (1981, 1991 and 2001). A recent survey is provided by Silber (1999).

8 Rankings changes are typically among mid-range countries — one has to really torture the data to displace the United States from its first position in terms of inequality and poverty among OECD nations.

9 As an example, we can cite Forbes (2000, p. 874) who, in an explanatory note, says: "As in Deininger and Squires, I have added 6.6 to Gini coefficients based on expenditure (instead of income)." Although it is true that Deininger and Squires do this and also that their data has been used without reflection by many, it is precisely this sort of casual mixing of quite different types of data that serious students of the issue find astounding.

10 Although Harris is quite in tune with the literature he summarizes in using the Gini index and the 90/10 ratio of annual money income as summary measures of inequality, he is not very specific about whether this is after-tax or before-tax income or whether it is household or individual income. If it is household income, it is very doubtful that the trend in family size distributions has been considered. All these issues matter since country rankings are sensitive to such measurement choices. Furthermore, the appropriate measure to use should depend on the theory being tested. For example, the Gini index is known to be more sensitive to differences in income in the middle part of the distribution, while the Theil index is more low-end sensitive. The argument that the inadequacy of income prevents parental investment in the human capital of their children is not an issue of relevance for the inequality among middle-class families or between the middle class and the highly affluent. This hypothesis is most relevant for families in the low end of the income distribution, and for the inequality of after-tax household income adjusted for family size and measured over a period of years. The Gini index of annual pre-tax incomes would not be a particularly good summary measure of the inequality of income to test the human capital transmission hypothesis, and the 90/10 ratio of individual incomes would be even worse — but the macroeconometric literature is seemingly unaware of these subtleties.

11 For example, both early childhood intervention programmes and pensions for senior citizens are likely to affect inequality (albeit in different senses of the term inequality), but whether or not they are good initiatives depends on their cost and the outcomes associated with specific programs, and not on any general macroeconometric relationship.

12 Osberg (1985) discusses why consumption and accumulation should be separately considered, since there are many reasons to believe that income flows are not always and automatically divided in an optimal fashion between consumption and accumulation.

13 The market price of slaves reflects the net value of future labour services, but it becomes an element of the capital structure of firms. By the current conventions of national income accounting, labour services that are not exchanged for cash (as in household production, or the voluntary sector) are not counted in GDP. Firms and households that employed their own slaves would therefore be counted as employing very little wage labour (overseers, presumably) and as having high labour productivity.

14 Even if the resource base were privately owned, this would not completely solve the problem. Private ownership might imply a system in which either (a) the resource depleted is sold explicitly to extraction firms or (b) the resources are owned by these firms. In the former case, resource rents appear in separate balance sheets from any profits due to greater efficiencies in resource extraction, while in the latter they are mingled. However, measures of sectoral productivity should not be affected by the proportion of private firms in each category.

15 If unlucky firms that suffer fire loss (for example) go bankrupt, while lucky firms are still in business at the end of the reporting period, sample selection bias may contaminate statistics on the productivity of technological change that involves greater risk.

16 One way of thinking about human capital risk is to imagine a two-stage process. In the first stage, people either maintain their human capital value with probability P_{ai} or are assigned to the reallocation pool with probability $(1 - P_{ai})$. Once in the reallocation pool, they draw their new human capital value from a distribution whose mean and dispersion varies with technological change and institutional structure, and with their personal characteristics. A person's human capital risk is a compound probability, but the elements of the process are worth distinguishing.

17 It is often forgotten that Marx himself had a very nuanced vision of the determinants of productivity trends in capitalist society. Although the core of Marx's analysis emphasized the tendency toward greater capital intensity of production and the class conflict between workers and owners, Marx also anticipated, in a generally positive way, modern trends toward the multi-tasked, multi-skilled worker of today. "Modern industry, indeed, compels society, under penalty of death, to replace the detail worker of today, crippled with lifelong repetition of one and the same trivial operation, and thus reduced to the mere fragment of a man, by the fully developed individual, fit for a variety of labours, ready to face any change of production, and to whom the different social functions he performs, are but so many modes of giving free scope to his own natural and acquired powers." (Marx, 1887/1967, p. 488)

18 The ECONLIT DATA base has 200 hits on the term *social capital*, only 46 of which date from 1995 or before. The term *social cohesion* has 59 hits, of which 25 date from 1995 or before.

19 Thanks to my colleague Mel Cross for this citation, and others similar.

20 De Tocqueville devoted Chapter VIII of his second volume to how *The Americans Combat Individualism by the Principle of Interest Rightly Understood.* He claimed that the Americans show with complacency how an enlightened regard for themselves constantly prompts them to assist each other, and inclines them willingly to sacrifice a portion of their time and property to the welfare of the State.

21 The literature on socio-economic determinants of health (e.g. Lavis and Stoddart, 2000; Wilkinson, 1996, 1999) has clearly identified both individual characteristics, like education, and societal characteristics, such as the level of economic inequality, as highly important determinants of individual health — arguably considerably more important than medical interventions are for life expectancy.

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Social Policy and Productivity Growth: What are the Linkages?

INTRODUCTION

THE EQUITY VERSUS EFFICIENCY ARGUMENT has been the bread and butter of economic policy and social policy discussions since the emergence of the modern welfare state in the post World War II period. In virtually all aspects of policy, the twin goals of promoting economic progress and social justice stands as a hallmark of the modern industrial democracy. By the late 1960s, the general view was that a conflict existed between the efficiency objective and the equity objective, nicely summarized in Okun's famous 1975 book: *Equality and Efficiency: The Big Tradeoff*.[1] In the 1990s, a new debate has emerged covering similar, although conceptually different, ground. Productivity growth is widely regarded as the major long-run determinant of per capita income growth in industrial countries. Over the last two decades, economists have been preoccupied with understanding the sources of productivity growth, and slow productivity growth in Canada has been a major policy concern for several years. Prior to the mid-1980s, traditional economic analysis focused on the static effects of economic policy — the so-called size-of-the-pie effects. For example, when looking at the impact of taxes on labour supply, the analysis was concerned with the one-time effect an increase in wage taxes could have on the labour supply, rather than its effect on long-run economic growth. However, it is evident that, in the longer term, how fast the pie grows is more important. The reason is simple: a small change in long-term growth rates — on the order of 1.0 percent, or even less — has dramatically larger consequences than a similar percentage change in GDP. This explains the emphasis put, in both research and policy, on understanding the factors leading to higher, or lower, productivity growth, as opposed to other factors that do not have permanent consequences on growth. Social policy might well be one factor that could have an impact on growth. The expansion of the welfare state was heavily dependent on strong economic growth in the 1950s and 1960s. The fiscal repercussions of slow productivity growth, which had set in by the mid-1970s and were evident in a debt and deficit build-up by the mid-1980s, raised concerns about the sustainability of high social spending. For both of these reasons, the dynamics of social policy became inevitably linked with the issue of economic growth.

That growth depends on productivity is not a fact in serious dispute; but the long-run sources, or ultimate determinants of productivity growth, are not completely understood. At the most general level, this is Adam Smith's question: What are the sources of the wealth of nations? At a more restricted level, there is agreement on the proximate sources of productivity growth — new investment, human capital formation, new technology and product innovation. What drives these factors in an economy has been accounted for largely by economic determinants, that is those impinging directly on investment, innovation, education and trade, which appear to have a direct and medium-term impact on productivity growth. However, recent research has put forward the hypothesis that social factors may also be a major determinant of productivity growth. Social factors would include the distribution of income and wealth in an economy, the range of social policy interventions including health, education, labour market regulation, and a variety of income support programs. These social policies may be defined to include the tax–transfer system, which finances the social budget. The implications of this change of perspective are potentially quite powerful in making a case for social policy. If it could be established that social determinants are a quantitatively major factor in productivity growth, then the traditional efficiency–equity tradeoff may not exist. Social policies to promote equity could also be defended on grounds that they simultaneously increase economic growth. The tradeoff is replaced by a virtuous circle in which equity-enhancing policies also promote economic growth. This paper provides a critical evaluation of these arguments.

In the paper, we present a survey of the evidence and debate on the social determinants of productivity in the context of the Canadian productivity debate. The paper examines both the basic theoretical arguments and the evidence advanced by economists, and their relationship to what might be called modern social policy. Not all social policy is directly motivated by equity considerations. In particular, modern social policies in the area of education and health focused on promoting the growth of human capital represent one category where both the evidence and debate on the growth effects are qualitatively different than in other areas of social policy.

It is instructive to consider the context in which this often heated, and at times politically loaded, debate surrounding the impact of social policy on economic growth has taken place. Three trends have been driving the wider debate in industrial countries — all of which are noticeable in Canada. First, the slow growth in Europe, particularly of employment, had led many to put the blame on the welfare state.[2] Eurosclerosis became the term employed to describe the slow growth and poor employment record of a number of European countries through the 1980s and early 1990s. A parallel debate in the Scandinavian countries has led many to the conclusion that the Scandinavian welfare state had similar consequences. Assar Lindbeck's critique is one of the most well known.[3] Part of the European record was the perception that generous social programs were a major factor responsible for the poor growth record. This debate was fuelled in part by the famous *OECD Jobs Study* (1994), and an attack by all OECD governments on the growth of debt and deficits in the mid-1990s. It may well be that the factors behind the slow employment growth in Europe ultimately have little to do with long-term productivity growth; but in the popular debate, the impacts of the European welfare state on productivity, employment and fiscal policy tend to get lumped together. Canada is typically viewed as somewhere between the United States and Europe on the welfare state spectrum, so that these arguments have likewise played out here.

A second major element, of more recent origin, is the debate on the *new economy* in the United States in contrast with the slow growth in Europe. The long and extraordinary economic expansion in the United States throughout the 1990s was accompanied by high employment and strong productivity growth. While the sources of this growth remain a matter of discussion, the *new economy* hypothesis claims that it is driven by the impact of innovations in the information, communications and telecommunications fields, giving rise to an entirely new phase of economic development — the so-called Third Industrial Revolution. Prior to the recent surge in growth, beginning in the mid- to late-1970s but continuing into the 1980s, there was a significant rise in market income inequality in the United States and the United Kingdom. These trends have subsequently shown up in most OECD countries, including Canada, but in Europe particularly it appeared that inequality was not increasing to the same degree. The acceleration of growth in the United States during the 1990s led some to infer that inequality seemed to contribute to growth. The divergent U.S. and European growth patterns in the 1990s has brought the charge that the re-distributive and labour market policies responsible for eurosclerosis have also prevented Europe from experiencing the growth benefits of the *new economy*. Economic growth and the preservation of equality as seen through this debate appear to be conflicting goals, reinforcing the old view that equity and growth are in opposition with one another.

Thirdly, an intellectual challenge to the existence of an equity-efficiency tradeoff emerged at about the same time the eurosclerosis debate began. From the mid-1980s, economists began to seriously re-think the sources of economic growth, which led to both to the New Growth Theory[4] and to a large empirical literature on the determinants of growth and productivity. The development of new data sets for a large number of developing and developed countries allowed researchers to pose new and interesting questions about the sources of growth. Much, if not all, of the intellectual impetus to discover links between social factors and growth are found in this literature on cross-country growth comparisons. In the early 1990s, a number of researchers identified a robust negative empirical correlation between measures of inequality and economic growth — lower inequality would be associated with higher growth. Other researchers began to look for other policy determinants of growth, many of which bear directly or indirectly on the issue of social policy, such as education and fiscal policy. Lastly, a voluminous literature emerged on the rising wage inequality in advanced industrial countries over the last two decades. While not directly about productivity and social policy, the wage inequality issue figures prominently in the productivity–social policy debate for a simple reason. Much of this literature adopts the opposite perspective — what is driving inequality is economic growth, which in turn is driven by technological change. From this perspective, understanding the consequences of any policy intervention on inequality and growth requires an understanding of the complex interaction between technological change, productivity growth, and its implications for wages and employment.

My purpose in this paper is to try to make sense of these often seemingly contradictory pieces of theory and evidence linking social policy to economic growth. Essentially the paper looks at four areas of research: i) the growth and inequality debate; ii) the small but growing literature on the policy determinants of economic growth; iii) an examination of two specific social policies — education and health; and iv) the literature on major technological change, wage inequality and the *new economy*. To provide the context for this discussion, the paper also includes some background material on economic growth, productivity, and social policy in OECD countries.

By way of a caveat, the paper is focused specifically on issues that are pertinent to Canada, or at least to countries like Canada — a democratic, high-income, small, open OECD economy. Nothing in what follows is meant to prescribe what development strategies are, or are not, appropriate for the developing world. The paper does not discuss the other main objectives of social policy that are not directly related to growth. Lastly, the paper does not discuss two areas of social policy that do have growth effects but are not directly related to the productivity issue. These are: a) the consequence of social security reform on savings — a very active debate driven by the aging population issue; and b) the effects of labour market regulation on employment, which have been extensively discussed since the release of the *OECD Jobs Study*.[5]

My main conclusion is in the form of a non-conclusion. This is one case where strong policy conclusions are well ahead of both theory and evidence. Neither provides conclusive support for the proposition that either a) policies directed at reducing inequality will increase productivity growth or b) increased social spending will raise productivity growth. Both advocates and opponents of such policies will find little comfort in these conclusions. Advocates, for the obvious reason that they are left in the position of dealing with the charge that equity and efficiency are often conflicting goals. Opponents, because the evidence is often sufficiently indecisive to leave ample room for *a priori* reasoned arguments to the contrary. Lastly, it is important to stress that most of the research is relatively recent. It is entirely possible that the balance of evidence may shift one way or the other as new studies are published.

Some Background: Productivity Growth and Social Policy

Productivity Growth: Concepts and Framework[6]

ECONOMIC GROWTH IS MEASURED as an increase in real economic output per person at the national level and is generally regarded as reflecting four factors :

- capital accumulation,
- employment growth relative to population growth,
- external market factors, and
- productivity growth.

Of these four factors, productivity growth has generally been found the most important for industrial countries. However, all the other factors can play an important role at various times. For example, a sudden increase in the fraction of the population that is employed would have substantive effects on growth for a few years. Moreover, a strict additive decomposition of these four factors could easily lead to incorrect inferences as to what is driving growth. For example, an increase in productivity growth caused by the availability of new technologies can lead to higher investment, which has an additional knock-on effect on the growth rate. Causality can also run the other way — investment can carry spillover effects through improved knowledge flows, leading to higher productivity.

The *productivity* of an economic activity is defined by economists as the ratio of an index of outputs to an index of inputs. It can be defined at the level of an individual performing a certain task, a plant producing a particular good, a firm carrying out a diverse set of economic activities, an industry, or an entire country. Productivity goes up when you can get more output with the same inputs. The definition of productivity hinges critically upon how one measures the inputs and the outputs. In the economic literature, the starting point is a production function depicting a microeconomic relationship at a point in time and mapping input to outputs. So we write, for example:

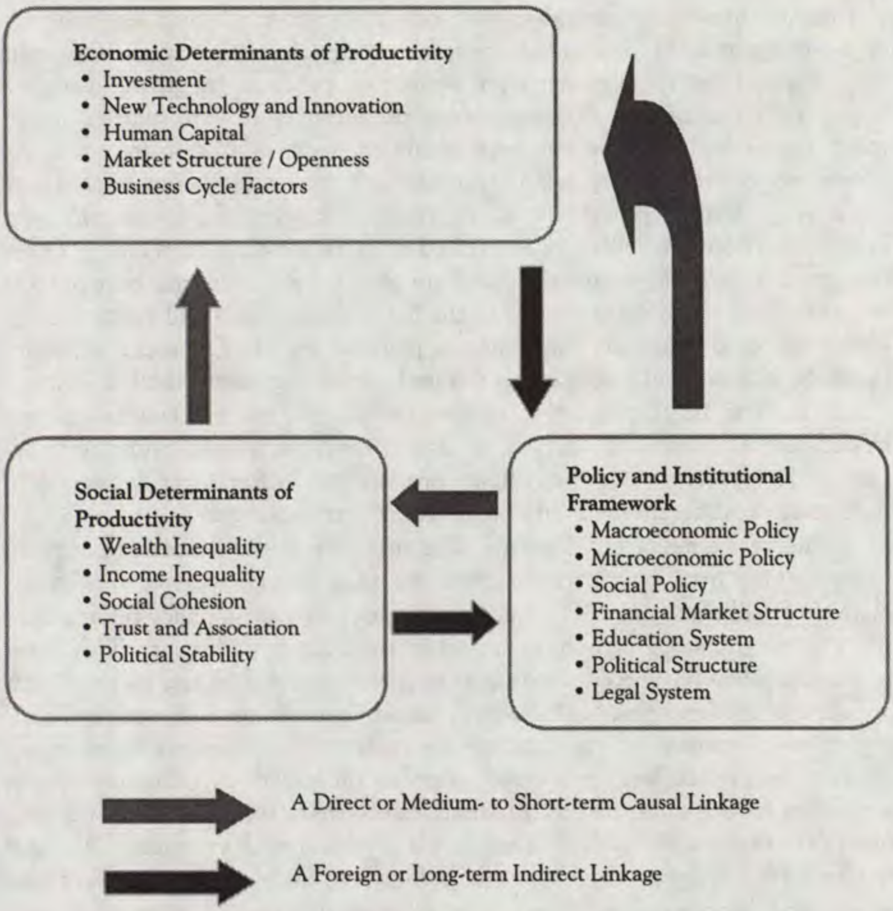
$$Y = AF(K, L),$$

where Y is output, K and L are measures of capital and labour, $F(\blacklozenge)$ is a time-invariant functional relationship between capital and labour, and A is a time-varying parameter, referred to as an efficiency parameter or total factor productivity (TFP) parameter. The productivity level is defined as the output per unit of labour input — the average labour productivity — either per worker or per hour worked, defined as Y/L. In this framework, productivity growth is the sum of two effects: the increase in the TFP parameter A, and the increase in capital per worker K/L. This approach is extremely well known and is used at both the individual micro-unit level and at the level of the entire economy.[7] In the latter case, output is measured as real GDP, and L is either the working population or the total number of hours worked. At the macro level, A is also referred to as the *stock of knowledge*, in line with the recent emphasis on knowledge as the truly ultimate determinant of technological feasibility. In practice, growth in A is invariably done by attributing to it what other factors cannot explain. In macroeconomics, this is often referred to as the Solow residual. For most industrial countries, growth in labour productivity is accounted for by changes in A, while relatively little growth is accounted for by changes in capital per unit of labour. However, the range of estimates vary considerably.[8]

While this framework is conceptually simple and widely used because productivity growth can be identified by the residual method (i.e. the change in A calculated by subtracting from the growth in Y a weighted average of the growth in K and L), it has long been recognized that this approach presents some serious shortcomings. In particular, there is no institutional context describing how economic incentives are determined, where new technology comes from, or what factors determine investment. The major accounts of the industrial revolution or of economic development offered by economic historians place great emphasis on these last factors.[9]

FIGURE 1

A CONCEPTUAL FRAMEWORK FOR THE ANALYSIS OF PRODUCTIVITY



A more general diagram depicting the determinants of productivity growth is given in Figure 1, which distinguishes between three interrelated categories — the economic determinants of productivity, the social determinants of productivity, and the policy and institutional framework in which these factors interact. The arrows indicate the possible directions of causality running between the three sets of interrelated factors. It is conventional to distinguish between the direct effect and the indirect or feedback effect each of these variables has on each other. It is generally agreed that investment, particularly in machinery and equipment, has the most direct measured impact on business sector productivity. This shows up in both country micro-studies and cross-country studies. Many social determinants could have an impact on productivity growth through their effect on investment. For example, greater political stability contributes to investment growth by reducing uncertainty; this higher investment in turn raises productivity growth, which leads to high economic growth. More generally, government policies — economic and social — probably have some medium-term effect on productivity growth via their impact on the economic determinants of productivity growth, such as investment. However, both economic and social policy also impact on the social determinants of productivity growth. For example, education policy affects both the average level of human capital in the economy and the longer run wage distribution between skilled and unskilled workers, which in turn affects future investments in human capital. There are also linkages running between the economic and social determinants to the list of institutional and policy factors. Greater income inequality can influence political decisions on social policy for example, which would have second round effects on growth and inequality, and so on. For the purposes of this paper, these highly indirect factors will only be occasionally mentioned, largely because there is not a lot of evidence to appeal to. However, they certainly figure prominently in the larger debate about the sources of differences in national economic performance.[10]

One of the major problems affecting research on the deeper causal pathways running from policy to growth is the time frame involved. Tax policy changes are likely to affect investment next year; education policy reforms may not change the stock of human capital in the economy for years. This time-horizon problem has forced researchers to use empirical data and methods that are capable of identifying medium-term measurable linkages between particular inputs and economic growth. Much of the cross-country research, for example, tries to identify the long-term effect of policy on growth by using averages of long-term growth rates over long periods, often two or more decades, and samples of countries with vastly different levels of economic development. The difficulty with this approach is that one is forced to assume that the effect of a given variable on growth is the same for all countries, thus ignoring potentially significant differences between countries in the way a given policy or social factor might impinge on growth.

As discussed in a companion paper to this (Harris, 1999), the bulk of the micro evidence on productivity is primarily about the so-called economic determinants. This reflects both data availability and the fact that economic theories linking these factors to productivity growth have received a lot more attention from economists than potential social determinants. We now turn to a description of where this evidence stands, and a review of recent trends in social policy.

ECONOMIC DETERMINANTS OF PRODUCTIVITY

THE BULK OF THE PRODUCTIVITY LITERATURE is concerned with either a) measuring productivity, or b) attempting to assess the quantitative importance of a set of limited economic determinants, largely at the microeconomic level but also at the macroeconomic level. The determinants that have received the most attention include investment, human capital, innovation and diffusion of technology, effects of international and domestic competition, various forms of knowledge spillovers, and most recently geographic agglomeration of economic activity. The success of these explanations has varied. Beyond the first four explanations, the measured effects are highly variable and in many cases difficult to detect statistically.

The social policy–inequality–growth debate has been partially motivated and conducted almost entirely within a macroeconomic framework focused on national comparisons. This is not surprising since differences in social determinants are generally regarded as having systemic economy-wide effects that would tend to impact on all sectors of the economy. The search for empirical regularities has therefore largely focused on differences between economies, averaged over a number of years. Attributing differences in productivity growth across time within a national economy to a single policy is fraught with difficulty. In particular, the fact that so many economic variables tend to trend together make it impossible to prove the importance of one particular factor relative to any number of others. The most prevalent form of evidence that has been offered in the modern debate, therefore, is either reduced-form or structural growth equations in which the variable to explain is the average growth of GDP per worker, or per hour, across a number of countries. Researchers in this area are well aware of the possible complex causal relations linking these variables at the aggregate level. Success may thus be judged by the standard scientific criteria of demonstrating that a few variables explain the data fairly well, or that particular variables show up repeatedly as quantitatively significant, despite variations in the data or statistical methods used. So far, it has been difficult to show that the economic determinants do a fairly good job in explaining the growth experience of countries at all levels of economic development.

Using a full sample of countries at all stages of development and only a limited set of economic variables leaves a lot to be explained. In discussing this issue, Hall and Jones (1999) point out that vast differences in income levels cannot be explained by savings behaviour or even measured human capital levels:

> Output per worker in the five countries with the highest levels of output per worker in 1988 was 31.7 times higher than output per worker in the five lowest countries (based on a geometric average). Relatively little of this difference was due to physical and human capital: differences in capital intensity and human capital per worker contributed factors of

> 1.8 and 2.2, respectively, to the difference in output per worker. Productivity, however, contributed a factor of 8.3 to this difference: with no difference in productivity, output per worker in the five richest countries would have been only about four times larger than in the five poorest countries. In this sense, differences in physical capital and educational attainment explain only a modest amount of the difference in output per worker across countries.
> (Hall and Jones, 1999)

International productivity differences (in levels) are enormous and any coherent explanation will have to rely on institutional and social infrastructure factors. The relevance of this to the OECD countries — many have very similar levels of economic development and quite similar institutional structures — is questionable. For these countries, similarities in institutions and developmental stages imply that the sources of growth are more likely to be found in a common set of factors. Most economic theories simply assume the problem away. Contemporary growth theory largely assumes a well-functioning market system with efficient financial markets, and markets that clear (most of the time) for labour and capital. Are these theories — now textbook material for most graduate students — capable of describing the modern economic growth experience of advanced countries? The answer is not a decisive yes or no, but as we will see below, the support for these models in the case of industrial countries is fairly good. In general, however, the task they face is considerably less daunting than it is for models attempting to explain what Hall and Jones describe, given that the maximum difference in income levels can be expressed as factors of 2 to 3.

Growth theory and empirical work have made some progress in the last decade toward reducing the uncertainty surrounding the determinants of industrial country growth. Temple (1999), for example, is cautious but optimistic in his assessment of the literature. I would summarize the evidence on modern empirical growth models as involving three stages — the reduced-form literature, and then the structural models of growth — without and with explicit transitional dynamics.

First, in the cross-sectional reduced-form literature, there is a consensus that relatively few variables are statistically robust in a growth equation.[11] In a growth equation, average labour productivity growth is the dependent variable with a set of potential explanatory variables on the right-hand side. The *successful* variables include:

- the initial income level at the beginning of the period,
- investment-to-GDP ratios,
- schooling levels,

- population growth, and
- indicators of openness in trade and/or foreign direct investment (FDI).

Temple (2000) survey this literature and notes that given the lack of an explicit theoretical structure, a large number of variables have been tried and the whole literature suffers heavily from data mining. That said, the growth regression literature has been very influential, although more so with respect to developing country issues than advanced country issues. The early work also revealed a number of variables that, to some, were not good explainers of growth. These included fiscal policy, R&D measures, and various political and legal variables.

Second, an important structural model of growth is the Mankiw-Romer-Weil (1992) augmented Solow model. This is the basic neoclassical growth model of Robert Solow with exogenous savings in physical capital, to which is added a third factor input — human capital. This is all done within a constant returns to scale aggregate production framework. The model is empirically implemented by imposing a steady-state restriction which implies that countries are on a steady-state long-run growth path for the period examined. Under this assumption, growth rates (the dependent variable) can be expressed without reference to the stocks of physical or human capital, but as functions of the savings rate, a schooling variable, and an initial productivity level assumed to be randomly distributed across countries. Attempts to make this model fit OECD cross-sectional data have not met with much success. This can be regarded as either a failure of the theory or a reflection of the fact that the steady-state restriction is too constraining.[12]

Third, the 1990s have brought a variety of structural growth models that incorporate human capital and drop the assumption that observed growth is of the steady-state kind. By incorporating dynamic transition effects to allow theoretical growth rates to vary over time, the models have met with somewhat more success. Barro (1991) was an early pioneer in this area, but numerous methodological, measurement and econometric improvements have been made over the last decade. A good technical survey of this literature is provided by Durlauf and Quah (1999), and it is covered in part in the Barro and Sala-i-Martin (1995) textbook. More significantly, the most recent versions of these models use panel data that exploit both cross-sectional and time series variation and are estimated using a variety of what are referred to as *dynamic panel methods*. Initially, there was some debate about the way in which the human capital variables should enter the model and some of the early results on human capital were quite odd. However, this human capital paradox has recently been largely resolved. Many of these estimates support the view of close to non-diminishing returns to a broad measure of human and non-human capital. Non-diminishing returns imply that increases in broad capital per worker yield incremental output increases that do not diminish as more capital is added. This comes very close to supporting what is known as *endogenous* long-run growth. Endogenous growth, as developed by Romer (1990) and Lucas (1988), occurs when a policy variable, such as the savings rate, can have a permanent effect on the *growth rate* as opposed to the long-term level of income. Non-diminishing returns to capital are a sufficient condition for a growth model to generate endogenous growth. A model exhibits exogenous growth when policy variables have only transitional effects on growth rates, although they can impact on steady-state levels of income. The Mankiw-Romer-Weil model is an example of an exogenous growth model.

Measurement and data issues have turned out to be quite important in this literature. Changes in data on capital stocks, human capital and specific economic policy variables have tended to have a substantial effect on estimated parameter values.[13]

Policy enters these models either as an additional explanatory variable or as a structural characteristic of the model. While in principle one can distinguish between endogenous and exogenous growth models, empirically identifying the effect of a policy variable on the steady-state income level *versus* the medium-term growth rate has proven to be very difficult with data sets covering 20 to 30 years. This is simply because convergence in these models is relatively slow and when the share of profit and returns to human capital becomes high (on the order of 2/3 or greater for most high-income countries), endogenous and exogenous growth models begin to behave qualitatively in a very similar fashion. A lot of the most recent literature works largely within an augmented Solow framework, in which policy impacts on the transitional growth rate, although the effects can last for a couple of decades. Policy is often discussed in terms of its impact on the *rate of convergence*. This refers to the fact that holding policy constant, these theories predict income levels that tend to converge to the steady-state income level. The rate of convergence is defined by reference to how long the process takes. Typical estimates are in the range of 15 to 30 years. When an economy is out of steady-state growth, which is usually assumed to be the case of interest, changes in policy impact on the rate of convergence as well as on the long-run level of income. Other things being equal, a policy that raises long-run income and has a shorter period of convergence is to be preferred over one that has a longer period of convergence.[14]

A recent paper by Bassanini, Scarpetta and Hemmings (2001) provides a good example of the use of this type of econometric model for a cross-country analysis of growth in OECD countries over the 1971-98 period with a specific emphasis on economic determinants. The basic growth model is a dynamic version of the augmented Solow model discussed in Chapter 5 of Barro and Sala-i-Martin (1995) with human capital and R&D. Policy variables interact with accumulation variables and also have a potential impact on long-run steady-state levels of productivity. The model does not impose similar dynamics on all countries — rates of convergence are allowed to vary among countries, but it does assume that in the long run all countries are governed by similar parameter values up to a constant level of difference between countries. The model does quite well at tracking the data and the authors provide an illustrative decomposition of the factors that determine aggregate productivity growth. The set of variables that explain growth includes a group of baseline variables (those derived from the basic theory) and a group of economic policy variables that shift the growth path:

Baseline variables:

- the initial productivity level,
- the share of investment in GDP,
- population growth, and
- human capital.

Policy variables:

- trade intensity,
- R&D expenditures,
- inflation variability,
- government investment, and
- government consumption.

In the estimation of the model, government investment turned out to be insignificant, while the R&D variable had to be dropped due to limited country coverage, although both were significant on a more limited data set. Table 1 reports the decomposition of the growth rate for each country expressed as a deviation from the OECD average. Looking at the row for Canada, we see that the country's annual growth rate of labour productivity was 0.23 percentage points above the OECD average for the period. The last column reports the country-specific residual effect, which is that part of the growth differential unexplained by the model. For Canada, it turns out that 0.32 percentage points of

TABLE 1

ECONOMIC DETERMINANTS OF ECONOMIC GROWTH IN THE OECD, 1971-98

COUNTRY	ANNUAL AVERAGE GROWTH RATE	GROWTH DIFFEREN-TIAL	INITIAL CONDITION GDP/POP.	INVESTMENT SHARE	HUMAN CAPITAL	POPULATION GROWTH	VARIABILITY OF INFLATION	GOV. CONSUMP.	TRADE EXPOSURE	RESIDUAL COUNTRY-SPECIFIC EFFECT
Australia	1.68	0.13	-0.37	0.20	0.52	-0.25	0.03	0.01	-0.41	0.40
Austria	1.57	0.02	-0.41	0.07	0.26	0.01	0.05	0.00	0.03	0.01
Belgium	1.66	0.11	-0.53	0.02	-0.15	0.20	0.03	-0.05	0.53	0.06
Canada	1.32	0.23	-0.90	-0.21	0.62	-0.18	0.04	-0.07	0.14	0.32
Denmark	1.69	0.14	-0.57	0.28	0.21	0.12	0.02	-0.14	-0.05	0.27
Finland	1.82	0.27	0.51	0.05	0.02	0.15	0.00	-0.06	-0.26	-0.14
France	1.35	0.20	-0.59	-0.09	-0.10	0.07	0.07	-0.08	0.05	0.48
Greece	1.15	-0.40	2.00	0.19	-0.56	-0.07	-0.16	0.17	-0.51	-1.48
Ireland	3.02	1.47	1.54	-0.18	-0.32	-0.18	0.01	0.09	0.17	0.34
Italy	1.73	0.18	0.22	-0.13	-0.69	0.13	0.02	0.01	0.14	0.48
Netherlands	1.26	-0.29	-0.47	-0.03	0.25	0.01	0.06	-0.13	0.52	-0.50
New Zealand	0.53	-1.02	0.34	-0.17	0.31	-0.29	-0.07	0.10	-0.36	-0.87
Norway	1.72	0.17	-0.12	-0.05	0.35	0.07	0.03	-0.06	-0.04	-0.01
Portugal	2.15	0.60	2.56	0.58	-1.20	0.07	-0.10	0.10	0.11	-1.52
Spain	1.28	-0.27	0.73	0.04	-1.12	0.00	0.03	0.07	-0.14	0.11
Sweden	1.20	-0.35	-0.60	-0.10	0.21	0.11	-0.10	-0.17	0.01	0.30
Switzerland	0.81	-0.74	-1.75	0.08	0.59	-0.04	0.00	0.15	0.02	0.21
United Kingdom	1.63	0.08	0.05	-0.21	0.17	0.15	-0.03	-0.02	0.31	-0.34
United States	1.93	0.38	-1.62	-0.34	0.63	-0.09	0.07	0.09	-0.25	1.89

Source: Bassanini, Scarpetta and Hemmings, 2001, Table 9.

growth are unexplained. Factors that impact on Canada's growth relative to the OECD average include:

- A high initial income, which tended to reduce Canada's growth relative to other OECD countries which started the period at much lower productivity levels;
- A share of investment in GDP that was lower than in other countries;
- Human capital levels that account for a large positive effect on the Canadian growth differential (0.62 percentage points per year);
- Openness to trade, which accounts for a positive 0.14 percentage points growth differential; and
- Population growth, government consumption levels, and inflation variability, which account for very little of the growth differential.

The model performs well except for two countries — Greece and the United States. The authors note that Greece is an unusual case that also raises some data issues. However, the U.S. results are quite interesting. The large positive unexplained residual for the United States reflects the inability of the model to explain the acceleration of labour productivity growth in the 1990s — an issue to which we shall return later. To that extent, it is clear that the explanation of growth being offered by this model is less than complete. Nevertheless, the model provides an impressive example of how far modern theory and econometric methods can go in terms of explaining the growth performance of industrial countries. Providing explanations for the country-specific effects remain an important issue. There could be either social determinants or other unaccounted for economic determinants at work. It is important to emphasize that it would appear that a large portion of economic growth can be accounted for by a relatively small set of determinants.

Social Policy

THE BASIC POLICY QUESTION TO BE ADDRESSED is the extent to which social policy might have consequences for productivity. As most of the empirical work in the area hinges on differences among countries in social policies, this section provides a brief review of some indicators of social policy. In Canada, social government expenditure cover a range of public sector activities. A typical classification scheme based on public finance theory would be as follows:

Public goods and services — *Pure* public goods such as national defence and general public services such as administration, legislation and regulation.

Merit goods and services — Quasi-public goods provided on grounds of market failure, externalities or economic justice principles. For example, government provision of education is common because citizens may ignore the social returns of human capital investment, or have limited access to capital markets. Health care is another example.

Economic services — Private goods or services prone to natural monopoly or strong externalities. Examples include public utilities and financial support for specific activities such as research and development.

Social transfers — Transfers providing support for income and living standards that have declined sharply, or to individuals who face exceptional expenses due to old age, disability, sickness, unemployment, family circumstances, etc.

Using this classification, social policy would tend to be defined in terms of spending under the *merit goods and services* and *social transfers* categories. An alternative perspective would be focus not on the classification of spending, but more directly on the goals of social policy. Social policy pursues a number of goals, including:

- increasing self-reliance,
- readjusting intergenerational burdens,
- improving flexibility and economic growth,
- reducing the incidence of low income and child poverty,
- improving the efficiency and quality of service delivery,
- improving public finances,
- improving social cohesion, and
- ensuring that basic social needs are met.

Clearly, economic growth is one goal, but only one of many, and almost certainly not the most important. The recent social policy debate in many OCED countries has tended to emphasize the cost side of the ledger. The *incentive cost* argument emphasizes that social protection can generate long-term welfare dependency and the capacity for flexible adjustment to shocks. The funding of social security contributions in the form of payroll taxes or general tax revenues increases the *distortionary welfare cost* of taxation. High social security and health care contribution liabilities for employers and other non-wage labour costs can lead to lower employment, especially for low-wage unskilled workers. All of these might contribute to lower productivity growth.

However, in principle, social programs can facilitate economic adjustment and thus economic growth. For example, unemployment benefits can provide replacement income while people search for a job. Social protection provides collective insurance to cover risks that may occur during a person's life (such as unemployment, sickness, disability, maternity), usually at a much lower cost than if such risks were insured privately, leading to increased investments in human capital and greater mobility. Active measures to encourage and facilitate labour force participation contribute to economic growth by enhancing the flexibility of the labour force. Policies to improve the health and safety of the workforce can increase labour productivity.[15]

Assessing the productivity effects of social policy is inherently difficult. Aside from the direct human capital effects, a lot of the impact is likely to be indirect, working through changes in incentives to invest, save or work or through the induced fiscal effects on similar variables. The search for empirical regularities linking growth to social policy is almost non-existent. OECD comparisons are inevitably going to be the data most discussed in this respect. To make matters worse, this comparative data is almost all related to expenditures — that is, it measures inputs to social programs but not their outputs, which would be preferable in a productivity study. The growth literature has investigated quite extensively two categories of public spending — public investment and government consumption. Generally, the results are mildly favourable toward the productivity or growth effects of public sector investment, and distinctly negative with respect to public sector consumption, as is illustrated by the results reported in the last section. However, neither of these captures what would be called various forms of social expenditure. Differences between countries in social spending is the only form of evidence available thus far to estimate the growth effects of social policy.

Using the public finance classification of spending, Canada tends to spend relatively little on what might be called public goods or economic services. Of total public spending, a great deal is accounted for by social spending. In 1995, public goods accounted for 2.6 percent of GDP, merit goods (health, education and other social services) 12.3 percent, income transfers 11.5 percent, economic services 2.4 percent, and interest on the public debt 9.6 percent. However, comparative numbers are more interesting. Table 2 compares Canada to two other countries perceived to be at opposite ends of the social policy spectrum — Sweden and the United States — with respect to spending on education, health and transfers. While there were substantial differences between the three countries in 1980, some convergence has occurred between Canada and the United States, but Sweden continues to standout in its spending on social transfers.

TABLE 2

SELECTED SOCIAL EXPENDITURES AS A PERCENTAGE OF GDP, CANADA, SWEDEN AND THE UNITED STATES

	1980	1990	1995
		HEALTH	
Canada	5.0	5.4	5.8
Sweden	8.4	7.6	5.7
United States	4.0	5.2	6.5
		EDUCATION	
Canada	5.4	6.7	6.5
Sweden	7.6	6.8	6.6
United States	5.3	5.3	5.0
		TRANSFERS	
Canada	8.1	10.8	11.5
Sweden	16.5	19.2	21.2
United States	9.3	8.5	9.4

Source: OECD, *Social Expenditure Database, 1980-1997*, 2000.

Here are some other characteristics of OCED social spending patterns worth noting:

- A well-established empirical regularity in public finance is what is known as Wagner's Law. The demand for certain types of social protection rises more than proportionately with the level of per capita income. While this relationship is not observed in a cross-section of countries, it holds very strongly in almost every national time series on public expenditure. This fact, usually explained by using simple arguments about voter preferences, implies that economic growth is likely to have a positive impact on social spending, confounding the detection of causal channels running in the other direction — from social spending to economic growth.

- Much of what government does is redistributive (Boadway, 1998), but the interesting fact is that the bulk of the redistribution is not from the rich to the poor. During the 1980s and 1990s, the reforms to the personal tax system in nearly all OECD countries and the pressure on public budgets meant that the generosity of benefit schemes was reduced. While benefit systems redistribute income, they do not primarily redistribute from the rich to the poor. Rather, they redistribute from young to old, from those who work to those who do not, and from childless families to families with children. Social policy, therefore, is not primarily directed at equity *per se* and its growth effects are dependent on the details of specific programs.

- There has been a general and persistent upward trend in total government spending within the OECD. From 1970 to 2000, the OECD average went from 29.2 percent to 36.5 percent of GDP. Canada went from 33.8 percent in 1970 to 46 percent in 1990, and then down to 37.8 percent in 2000 with the successive Martin budgets. The major factor to which most analysts attribute this growth is the creation and expansion of programs and the provision of services in the social policy area. The income support element of these entitlements is reflected in a persistent rise in income transfer payments until the mid-1990s.

The common social policy experience of so many countries points to the difficulty inherent in attempting to use these variables to explain differences in the growth experiences within the OECD. However, there are some notable differences as noted above, and these will prove important in the identification of the effects of social expenditures on productivity.

THE HUMAN CAPITAL DIMENSION OF GROWTH

MOST CANADIANS WOULD PROBABLY ACCEPT the proposition that the public health and education systems are part of the Canadian social program framework. These type of public expenditures, often classified as merit goods by public finance economists, provide the basic infrastructure for the maintenance and provision of human capital in Canada. While private sector provision of both health and education does occur in Canada, these are generally regarded as a critical public sector responsibility. While there is a great debate about how these services should be delivered, the resources that should be devoted to them, and their method of financing, there is relatively little public controversy and a strong presumption that both health and education expenditures contribute to the productivity of the labour force over the long term. That said, however, there remains the question of the order of magnitude of the impact of health and education expenditures on productivity in an advanced country like Canada. It is not uncommon to hear accusations that we have too many university graduates with the wrong kind of training or, in the health care field, that too much is spent on health. A balanced assessment of social policy effects on productivity must necessarily address these two critical issues. In the case of human capital, the level of uncertainty has been reduced considerably by more than three decades of economic research on education, human capital and productivity. Health presents exactly the opposite case — the uncertainty is large and probably unresolvable in the near term.

EDUCATION

PUBLIC AND PRIVATE EXPENDITURES on educational institutions account for about 6 percent of the collective GDP of OECD member countries. Canada has witnessed fairly significant increases in educational attainment levels but it spends close to the OECD average on education. How do these expenditures affect economic growth? In this section, we summarize the literature on education and productivity based on recent evidence. There are a number of useful surveys in the literature including Topel (1999) and Temple (2000). Economists working in this area have used vastly different methodological approaches. There are three broad approaches: i) the labour economics approach, which is based on individual micro-data sets for particular countries that look at wages and education; ii) the approach followed by macroeconomic growth economists who estimate growth models that rely on aggregate human capital as an input to production; and iii) productivity accounting studies that attempt to attribute growth in output to various factors, including productivity changes driven by increases in labour quality. This is, to put it mildly, a vast literature. The intent here is to hit the major points and provide some perspective on the Canadian figures.

Earnings Equations and Microeconomic Studies

The traditional labour economics approach to education is to estimate what is known as a Mincer wage equation or schooling function. Basically, market wages or earnings of individuals are regressed on a measure of schooling, an experience or age variable, and a number of controls for region, industry, and so forth. This literature has consistently shown that the private return to an additional year of education is in the 5 to 13 percent range, with a median estimate of 8 percent. (See Card, 1999, for example.) Note that this is the private return to schooling and not necessarily the social return. Therefore, increased schooling at the individual level can be associated with higher productivity if we assume that wages are paid according to productivity.

Macroeconomic Studies of Human Capital

Macroeconomists concerned with explaining national growth performance have generally worked within an aggregate production framework amended to include human capital. Thus, GDP is generated by an aggregate production function of the following form:

$$Y = AF(K, H, L),$$

where A is the TFP parameter defined earlier and H is a measure of human capital. By far, most of these studies, both for OECD countries and for developing countries, have used measures of either schooling enrolment or educational attainment, defined for the population or the labour force, as proxies for the human capital variables. Following Lucas (1988), many macro studies also attribute to human capital an indirect effect on TFP growth — it is assumed that either the level or the growth in TFP depends on the level of H.

The early macro studies[16] found the puzzling result that changes in output (Y) appeared unrelated or only weakly related to changes in human capital. This was completely at odds with the evidence on private returns to schooling and the considerable increase in average educational levels in the earlier part of the century, generally considered by historians to have been an important factor in early 20th century growth.[17] Many accounts of East Asian growth for example put a large weight on increases in educational attainment. Fortunately, this enigma has been resolved when researchers discovered a measurement error in international data on education. Recent improvements in data and econometric methods have yielded results very closely in line with the micro evidence on wages. De La Fuente and Domenech (2000) developed a much improved data set for human capital in the OECD, which is now used by a number of analysts. The crucial long-run elasticity of output with respect to human capital is estimated to be in the 0.6 range (see Bils and Klenow, 1998; Krueger and Lindahl, 1999; Topel, 1999; and Temple, 2000). This output elasticity implies that an additional year of schooling in the average working population raises output per capita by slightly less than 6 percent. This range of effects is entirely consistent with a standard production function framework.[18]

Many of the earlier results showed very large effects of human capital on growth but did so by using the level of human capital as a conditioning variable in a cross-section growth convergence relationship. This specification is subject to two interpretations — either a Lucas-type externality interpretation, in which one is picking up a human capital externality rather than a private return, or a conditioning variable interpretation in a Solow-type transitional growth equation. Unfortunately, it is difficult to distinguish between these two interpretations using cross-sectional evidence alone. Some of the estimates achieved within this framework are unreasonably high. For example, Barro and Sala-i-Martin (1995) estimated that a one year increase in average educational attainment raised steady-state per capita output by 30 percent. This macro evidence unfortunately does little to discriminate between countries; almost all these studies assume estimated parameters to be similar across countries.

Growth Accounting

An alternative methodological approach attempts to attribute changes in output to changes in input quantities, input quality and TFP changes. The growth accounting approach, which is heavily centered on detailed measurement, uses as its working assumption that wages reflect productivity. It assumes that returns to labour force quality, as measured by changes in educational levels, are reflected in wages. After reviewing the U.S. evidence for the 1950s and 1960s, Griliches (1997) concludes that this approach suggests that improvements in labour quality account for about 30 percent of the U.S. productivity residual — the growth in output that cannot be accounted for by the growth in the quantities of capital and labour employed. In the 1950s and 1960s, this would correspond to an impact on the aggregate output annual growth rate of around 0.5 percentage points. During the 1970s productivity slowdown, the effect of educational improvement would have been smaller, perhaps raising the growth rate by 0.2 to 0.3 percentage points.

The Canadian Evidence

The Canadian evidence on the issue of human capital effects on growth is mixed. The estimated rate of return is very similar to that of the United States, although as we shall see later the most recent trends may signal some divergences. The macro growth regression approach hinges heavily on the exact measure of human capital that is used. In the OCED results referred to earlier, the typical concept of human capital intensity is the average educational attainment. In Canada, the data on average years of schooling show a small but important increase — in 1970, the average was 11.37 years, and by 1998 it had moved to 12.94 years. As noted in our discussion of economic determinants, while apparently small, this increase goes some way toward explaining Canada's productivity performance relative to the OCED average. However, measurement methods matter a lot in this debate. More detailed attempts to measure human capital often produce quite different results. Laroche and Mérette (2000) have recently done some in-depth work on human capital stock estimates for Canada adopting what is called an income-based approach — using wages to impute directly a value to the stock of human capital. The authors compare two common measures of the total human capital stock. Canada's working age population increased by about 33 percent over 1976-96. Adjusting by years of schooling, this would yield an estimated increase in human capital stock of 73 percent. Using an income-based approach, however, the estimated increase in human capital stock is 89 percent. Their study also points out that the measures are sensitive to whether they are applied to the labour force or simply to the population as a whole. The authors also estimated that the total

TABLE 3

LABOUR QUALITY AS AN EXPLANATION OF THE PRODUCTIVITY RESIDUAL IN THE PRIVATE BUSINESS SECTOR, CANADA AND THE UNITED STATES
(AVERAGE PERCENTAGE GROWTH PER YEAR)

	1961-95	1961-73	1973-88	1988-95
		CANADA		
Value-added Growth	3.71	5.56	3.27	1.48
Contribution of Labour Quality	0.33	0.47	0.19	0.38
Solow Residual	1.68	3.22	0.92	0.66
Labour Quality as a Share of Residual	0.20	0.15	0.21	0.58
		UNITED STATES		
Value-added Growth	3.14	4.41	2.57	2.18
Contribution of Labour Quality	0.36	0.50	0.24	0.39
Solow Residual	1.44	2.65	0.86	0.64
Labour Quality as a Share of Residual	0.25	0.19	0.28	0.61

Source: Author's calculations based on Gu and Ho, 2000.

active stock of human capital has increased more rapidly than the conventional population-based measure, mainly as a consequence of the large number of increasingly educated women entering the labour force during the period. This parallels similar results obtained for the United States by Jorgenson and Fraumeni (1989). While these results have yet to be used to estimate productivity growth, they will almost certainly have a significant impact on that portion of productivity growth attributed to increases in human capital.

Recent Industry Canada growth accounting exercises for Canada and the United States provide another useful perspective on the human capital issue. Within this framework, increases in labour quality correspond to shifts in the labour input mix according to a classification based on sex, employment category, age and education. Looking at the residual (output growth not accounted for by increases in inputs), Gu and Ho (2000) find that from 1988 to 1995, labour quality increases in Canada accounted for 58 percent of the productivity residual. As is evident in Table 3, the contribution of labour quality toward explaining the productivity residual is similar in Canada and the United States. An interesting point is that for the 1988-95 period, labour quality accounts for a higher percentage of the residual in both countries.

Social versus Private Returns to Education

It is commonly asserted that the social returns to education exceed private returns, and this provides a major justification for public support of education. There has been an on-going debate on the extent of the gap between social and private returns, and the way in which social returns can be measured. Some recent efforts to infer human capital externalities using wage data at the regional level have met with limited success. A study by Rauch (1993) suggested significant spillover effects on individual wages from the average level of human capital in a U.S. state.[19] Basically, these exercises attempt to detect whether individuals who would otherwise be equal tend to get higher wages in regions with higher average wages. Aggregate growth models have also been used to measure the size of dynamic human capital externalities — externalities that directly affect the growth rate and operate through time. For example, more human capital facilitates innovation and the diffusion of new ideas, the benefits of which are not captured by the returns to individuals in the form of higher wages but impact on economic growth generally. While these dynamic spillovers are widely believed to be important, there is little direct evidence that bears on this issue. Given that the dynamic productivity effects of R&D are fairly well established and the fact that R&D is very human-capital intensive, and in light of other measures of innovation, it is probable that such effects exist but are compounded with other productivity determinants. Of course, all of this literature presumes that social returns to education have to be measured in terms of economic output.[20] This is simply not the case. After all, as Weiss notes (1995, p. 151):

> Education does not have to be justified solely on the basis of its effect on labour productivity. This was certainly not the argument given by Plato or de Tocqueville and need not be ours. Students are not taught civics, or art, or music solely in order to improve their labour productivity, but rather to enrich their lives and make them better citizens.

Even if one accepts the inability of these recent studies to pick up a significant human capital externality based on regional U.S. wage data, it would be seriously premature to take this as evidence that public support of education is not warranted on economic criteria alone. Removal of public support would almost certainly have the effect that many who now choose to become educated would not make that decision, for reasons linked to capital market imperfections. These studies are entirely consistent with the view that, at current average education levels, additional subsidies to higher education may not be warranted on externality grounds. But at very low levels of educational attainment, the social-private discrepancy may still be substantial for the usual reasons, and thus the arguments for public support of education are entirely valid. Finally, it would be absurd to ignore the growth miracles of the last 25 years. In almost every case — East Asia, Ireland, Finland — detailed accounts attribute a large share of economic success to either human capital upgrading, or the prior presence of a skilled labour force.[21]

Health

THE LINKS BETWEEN health expenditures, health and productivity remains both under-researched by economists and highly controversial. There are relatively few studies similar to those in the education sector that one can appeal to. What evidence exists usually points to correlations between income and health without resolution of the dominant direction of causality. Nevertheless, entirely reasonable interpretations of this data and the growth experience since the industrial revolution attribute more or less importance to health factors. In developing countries, there is better evidence on the link between health and worker productivity; but for the industrial countries, given the high levels of health already attained as measured by life expectancy, it is more difficult to identify the relevant marginal productivity effects.

There are a variety of ways in which health can affect productivity. A large proportion of the working population depends on general good health and well-being, including mental health, in order to function at work. One approach to identifying the productivity effect is a *cost of illness* calculation that measures lost worktime — an obvious loss of productivity. At a more general level, capital formation requires that a high proportion of the skilled labour force remains active for a number of years. The concomitant experience is important for technical innovations that take years of investments in research and development. By increasing the probability that workers remain on the job for long and uninterrupted periods, health re-inforces the willingness of firms to invest in new equipment and on-the-job training. Unfortunately, identifying these effects by conventional econometric methods has so far not been possible.

Historical accounts of economic growth sometimes attribute a large role to health in a general sense. Robert Fogel (1997), a prominent economic historian, has emphasized in his research the role that improved health played in the industrial revolution. He posits a *technophysio* evolutionary process, which is similar to genetic evolution in that it involves biological changes over time, but distinct in that it is faster, less stable, more directly anthropogenic, in interaction with technological change, and very recent.[22] The primary outcome of this process (beginning with the second agricultural revolution) has been rapid population growth and longer life expectancy, driven primarily by improvements in nutrition. Fogel argues that, over this period, Western Europe has seen rapid increases in both labour force participation rates and the average number of calories available for work, increasing productivity by about 0.3 percentage points per year. This trend, according to Fogel (2000) accounts for about half of Britain's economic growth over the past two centuries!

Preston (1976) analyzed cross-country data on life expectancy and national income for the approximate periods ending in 1900, 1930 and 1960, and observed that for a given income level, life expectancy was increasing over time. Moreover, per capita GDP above 600 dollars (in 1963 prices) had little impact in raising the highest life expectancy (approximately 73 years) in the 1960s. While recognizing that shifts in the income–life expectancy relationship had multiple causes, Preston attributed approximately 15 percent of the gains in life expectancy to income growth but was less optimistic about the role played by nutrition and literacy.

The debate continues on the causal links between health and socio-economic status in developed countries. The traditional public health approach focuses on policies aimed at improving health, based on disease oriented risk-factor epidemiology. This approach seeks to identify the social, behavioural and biomedical causes of disease. It has been heavily criticized by a number of physicians and social scientists. Prominent contributions to this debate by Canadians include Frank and Mustard (1994), Evans (1994) and Herzman (1996). The thrust of these arguments is that the health of a population can be explained by socio-economic success rather than the health care response to disease. It should be emphasized that these studies do not address the productivity issue directly. Rather, they focus more on a critique of the received wisdom on the determinants of health. However, one possible interpretation is that better health is more likely to be a function of good economic growth performance than additional expenditures on the health care system.

One would have to conclude that the productivity case for social expenditures on health in high-income countries, as conventionally carried out in modern health care systems, remains controversial. The lack of either detailed micro or macro studies linking health to productivity growth, and the unresolved debate amongst health specialists about the determinants of health, suggest that this uncertainty will not be resolved soon.

Inequality, Social Policy and Productivity

In this section, we review the theoretical and empirical literature that points to a causal linkage running from inequality and social policy to productivity growth. It is instructive first to assess what has been a key driving force behind the policy dimension of this debate — the recent changes in income inequality. Looking at the total income of the working population, the changes have not been as dramatic as one might imagine from the popular debate on this topic. In Table 4, the levels and changes of two standard inequality

TABLE 4

INEQUALITY LEVELS AND CHANGES, WORKING AGE POPULATION, MID-1970S TO MID-1990S

	LEVELS		ABSOLUTE CHANGES BBETWEEN PERIODS			
	GINI COEFF.	P_{90}/P_{10} DECILE RATIO	GINI COEFF.	P_{90}/P_{10} DECILE RATIO	GINI COEFF.	P_{90}/P_{10} DECILE RATIO
	MID-90S	MID-90S	MID-70S / MID-80S	MID-70S / MID-80S	MID-80S / MID-90S	MID-80S / MID-90S
Canada	28.7	3.9	0.1	0.1	-0.1	0.0
Sweden	24.7	3.1	-0.6	2.3	0.0	0.2
United Kingdom	30.4	4.1	3.7	2.7	0.7	0.4
United States	33.3	5.3	2.9	0.6	1.0	-0.1

Source: Förster and Pellizzari, 2000.

indexes, the Gini coefficient and the ratio of income of the 90th decile to the 10th decile are recorded.[23] It is well known that total income inequality rose in the United States and the United Kingdom from the mid-1970s through the mid-1980s. These trends were never as evident in other countries. However, from 1985 to 1995 the trends slowed somewhat. The effects on the distribution of income for the working age population are shown in Table 4 for four countries: Canada, the United Kingdom, the United States and Sweden. While the level of inequality of income of the working age population in Canada would be considered to be higher than in Sweden, there has been virtually no change from the mid-1970s to the mid-1990s. However, with respect to market income, the underlying trend has been similar in most countries. A recent OECD summary of the trends with respect to Canada is provided in Box 1.

What has happened in Canada is typical of a number of OECD countries — from the 1980s to the mid-1990s there was a fairly significant change in the distribution of market income toward the upper end of the distribution despite the relatively mild changes in total inequality, which measures income after taxes and transfers.[24] Specifically for Canada, from 1983 to 1995, changes recorded in the market income share of different deciles are presented in Table 5.

There is little doubt that this data has been a major factor behind the renewed interest in growth and inequality. Specifically, it is being argued that there is a causal chain running in the following sequence:

$$\text{Social policy} \rightarrow \text{Income inequality} \rightarrow \text{Economic growth},$$

BOX 1

INEQUALITY TRENDS IN CANADA

An OECD Summary

In Canada, the distribution of disposable incomes remained broadly stable over the last two decades, and some summary measures point to a slight decrease in inequality. This holds for both the working-age and the elderly population. During the first period, mid-1970s to mid-1980s, there was some "hollowing out" of the middle incomes, as both the bottom and the top incomes gained income shares at the expense of the middle incomes. This trend did not continue into the second period, from the mid-1980s to the mid-1990s. Real incomes, on average, did not improve in Canada over the last 10 years; they fell for the upper incomes while the real value was maintained for those at the bottom. There was redistribution across age groups in the last ten years: relative incomes of the elderly, in particular older senior citizens, increased more than in all other OECD countries (Austria excepted), namely by 3 percent for those aged 55 to 64, by 8 percent for those aged 65 to 74 and by 10 percent for those aged 75 and over. All other age groups lost ground.

As in most other countries, the share of market income, in particular capital and self-employment income, going to the bottom deciles among those of working-age decreased, and related to that, tax shares fell, too. At the same time, Canada is one of the few countries in which the transfer share of bottom incomes did not increase during the past ten years. Nevertheless, a decomposition of levels and trends in inequality among the working-age population shows that both taxes and transfers contributed to equalize the distribution of disposable incomes over time. As in a majority of countries, a process of "employment polarisation" took place in Canada in the last ten years. However, both fully employed and workless households increased their relative incomes while those of multi-adult households with only one worker fell. The contributions of these three groups to the slight decrease in overall inequality were different: while inequality within and between those groups contributed largely to the decrease, structural changes drove overall inequality up but did not outweigh the other decreasing effects.

Source: Förster and Pellizzari, 2000, pp. 36-37.

TABLE 5

MARKET INCOME SHARE LEVELS AND CHANGES, CANADA

	SHARE IN 1995 (PERCENT)	CHANGE OVER 1988-95 (PERCENTAGE POINTS)
Three Bottom Deciles	9.6	-0.9
Four Middle Deciles	35.5	-0.5
Top Three Deciles	54.9	1.4

with the presumption that increased income inequality lowers growth. The debate was given a great deal of impetus by two related developments in the field of economic growth. First, an empirical finding that claimed to show a positive link between lower inequality and higher growth, based on cross-sectional growth regressions. Second, some theoretical work in the *new growth theory* tradition which provided a rationale for this link. In this section, we look at both. Finally, it should be pointed out that it has long been recognized that causal links could also run the other way — from growth to inequality, although the sign of the effect is largely viewed as ambiguous. In the broad sweep of evidence on the industrial revolution and economic development, the received wisdom was summarized by a concept known as the Kuznets (1955) curve, which showed that as income levels rise inequality first increases and then subsequently decreases. However, the existence of an inverted U-shaped Kuznets curve says nothing directly about growth and inequality, other than to argue that as income levels get sufficiently large, inequality will fall.

GROWTH-INEQUALITY REGRESSIONS

EVIDENCE ON THE POSITIVE LINK RUNNING from inequality to growth was first provided by Persson and Tabellini (1994), who looked at cross-sectional and time-series data for both developing countries and OECD countries. They found a significant *order of magnitude* effect of inequality on growth. The equations were a reduced-form growth regression with per capita GDP growth as the dependent variable and controls for the initial GDP level (per capita) and schooling. They estimated that a 0.07 increase in the income share held by the top 20 percent of the population lowered the growth rate of per capita income by just under 0.5 percent — a very large effect. They argued that this result also holds for OECD historical data. Using a 70-country postwar data set, Alesina and Rodrik (1994) found that a one standard-deviation increase in the Gini coefficient of land distribution affects growth rates by 0.8 percentage points per year. A number of studies came to similar conclusions, although it is important to note that the majority of these studies were done with samples dominated by developing countries.[25]

Very few empirical variables that have been asserted to *explain* growth have not gone unchallenged. The same can be said for inequality both within OECD and developing country samples. Here are some of the issues that have been raised in the growth–inequality context:

1. Empirical growth regressions are very sensitive to the set of explanatory variables used. The significance and magnitude of coefficients often change when the set of explanatory variables changes. For example, most theory suggests that both investment levels and human

capital should be important conditioning variables. Barro (1999) noted this sensitivity and specifically found that when fertility rates are included in the full sample (developed and developing countries), the inequality variable becomes insignificant.

2. One of the major problems in this debate relates to the inclusion of both developing and high-income countries in the data sets. These countries differ not only in income per capita but also for a wide range of political and institutional factors. The convergence literature on developing countries has come to the conclusion that there appears to be evidence of non-convergence, suggesting that these differences are very persistent. How this should be dealt with statistically is a major issue. Purely cross-sectional methods have the disadvantage of imposing common parameters on a number of effects that might be expected to differ between countries at different levels of development. One way around this issue is to use dynamic panel methods of estimation that attempt to use both time-series and cross-sectional variation as a way of identifying the determinants of growth while controlling for country-specific effects.[26] One of the first to use this methodology with respect to the inequality issue was Forbes (2000), who found that once country-specific fixed effects were included, changes in inequality either had the opposite effect on growth rates, or were insignificant.

3. Arjona, Ladaique and Pearson (2001) adopt a panel approach to look specifically at this issue and at the level of development issue in a sample of OECD countries. They use the transitional version of the Mankiw-Romer-Weil model discussed earlier, in which growth depends on population growth, investment, initial income and human capital. They find virtually no evidence that inequality affects growth.

4. Another major issue is causality. A standard criticism of much of the cross-sectional growth literature is that one can never be certain that correlation is causation. Usually, there is an attempt to control for this by using data covering long periods of growth as well as conditioning variables measured at the beginning of the period. More sophisticated studies will often try to estimate a structural model in which the causal linkages are more precise. There are a number of different theories linking inequality to growth and the transmission channel is quite different in each case. It is unfortunate that there have been few attempts to identify the underlying structural link. For example, if increased inequality is assumed to lower human capital investment it would be useful to check if this structural relationship exists. Perhaps future work will

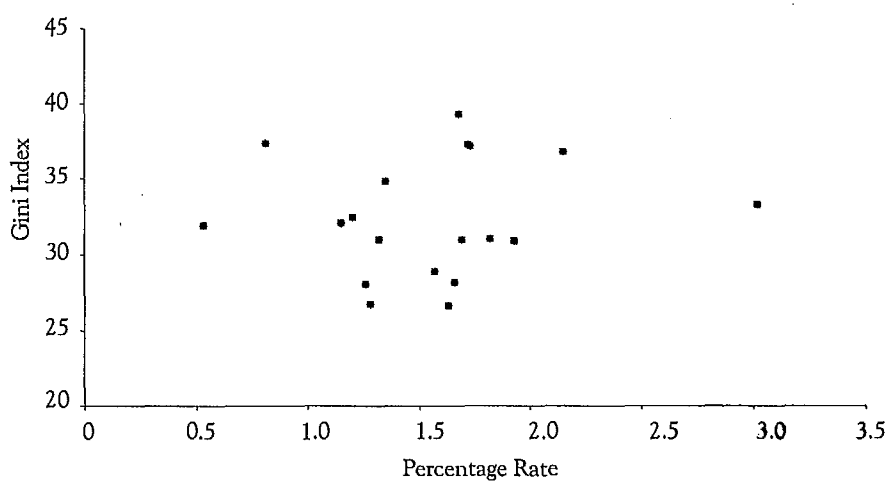
take this into account, but at the moment it is a major weakness of the underlying methodology.[27]

Should any of this be very surprising? Hardly. For two reasons. First, it has long been known that relatively few variables are robust in growth regressions.[28] Secondly, there is the basic data one has to work with. With a few exceptions, there is not much variation in inequality across OECD countries relative to developing countries. The United States and the United Kingdom tend to have higher levels of inequality, but their long-term growth performance has not been very different than that of most other industrial countries until very recently. The recent surge in U.S. growth has, if anything, added to the perception that the causality runs in the other direction. Figure 2 presents a simple plot of growth versus average income inequality.

The figure is plotted for the subset of older OECD countries (it excludes the recent joiners — Mexico, Korea, Greece, Spain, Portugal and Turkey). Not surprisingly, there is not much to be detected here using ocular statistical methods. The search for a more complicated correlation in this data is largely what the empirical debate has been about.

FIGURE 2

GROWTH AND INEQUALITY SCATTER,
AVERAGE ANNUAL PRODUCTIVITY GROWTH, OECD, 1971-98



On balance, the empirical case for a link running from growth to inequality for the high-income countries is at best statistically fragile, and at worst insignificant. Note that none of this points to the opposite conclusion — that increases in inequality cause higher economic growth.

The Theoretical Linkages

OFTEN IN ECONOMICS, in the absence of decisive evidence for or against a hypothesis, economic theory plays an important role in determining the priors of both economists as social scientists and as policy advisors. Part of the renewed interest in this debate is the new theoretical literature that shows that increases in inequality can hurt growth. Most of this theory is rooted in endogenous growth theory[29] in which productivity growth is an endogenous characteristic of the economic system. Recent surveys that focus on inequality include Aghion, Caroli and Garcia-Penalosa (1999) and Lloyd-Ellis (2000). As it turns out, however, these theoretical developments while insightful do not establish a strong case. They provide interesting examples of models where changes in inequality can lead to lower growth under highly specialized assumptions. To get these results, the models themselves must be dramatically simplified. Now this is not a criticism, but merely serves to point out that often in economics theory does not suggest a one-sided causal pathway between two variables. In this particular case, there is also an older literature that suggests the opposite effect — higher inequality can raise growth. There is also a political economy literature that emphasizes the endogenous nature of policy and growth consequences.

A brief summary of the theoretical arguments is provided below.

Traditional Theory

- Kaldor (1957): With savings-driven accumulation and assuming the rich have a higher propensity to save than the poor, more inequality leads to higher savings which can lead to higher transitional growth rates.
- Large investment indivisibilities: Assuming that capital markets are very imperfect, significant individual wealth accumulation may be necessary to make an investment. More inequality could help growth in these circumstances by facilitating the concentration of large pools of investment funds.
- Incentive- or Mirrlees-type (1971) theories: With imperfect monitoring of contracts due to transaction costs, moral hazard is to be expected. Borrowers using traditional debt contracts are quite likely to behave opportunistically and not always in the lenders' interest. In such

cases, optimal contracts should reward output, and with heterogeneity among borrowers the successful would be rewarded, not the unsuccessful. This implies a need for *ex post* inequality in rewards to maintain incentives. Similar arguments carry through to the taxation of savings in endogenous growth models driven by capital accumulation. By taxing savings growth is lowered (Rebelo, 1991). Both classes of arguments suggest that increased income inequality, as opposed to more equality supported by a highly progressive tax system, leads to higher growth.

Political Economy Models (Persson and Tabellini, 1994)

- Inequality affects taxation through the political process: In unequal societies, more voters prefer redistribution assuming the median voter determines policy outcomes. They consequently vote for redistribution, which reduces the incentives to invest, and hence lowers the growth rate. Note that this argument assumes that more inequality→more redistribution→less growth.[30]
- Social protection reduces growth through rent-seeking: This argument was made by Lindbeck (1975, 1995), who looked at the link between growth and social protection. He suggested that the universality of Scandinavian welfare states *politicised* the returns to economic activity and thus encouraged people to seek material gain through the political process by passing redistributive legislation rather than through entrepreneurial and innovative activity.
- A variant on the first set of theories, but with reverse implications assuming that interest groups determine policies and that a strong social safety net exists: In the presence of a free-rider problem, interest groups work hard at preventing policies that hurt them but that otherwise may have positive, widely-diffused growth effects (e.g. trade liberalization, labour market reforms, etc.). With social protection, these losses are partially insured against, thus reducing the opposition of interest groups to growth-promoting policies and increasing the likelihood that they will vote in favour of such measures.

New Growth Theory

Imperfect market and diminishing returns to investment: Aghion et al. (1999) refer to this as the opportunity-enhancing effect of redistribution with imperfect capital markets. Given diminishing returns to individual investments and restrictions on the ability of individuals to pool funds, people with high endowments have low marginal returns to investment, and conversely for the poor. Redistribution from the rich to the poor raises the average return and thus enhances growth.

Reversing of the traditional incentive argument: This argument stresses the Mirrlees' case, but with the added assumptions that the effort of borrowers is related to initial income and that limited liability effects are important. Let's assume that the probability of success of an investment project depends on the effort of the borrower, but that moral hazard exists for the usual reasons. With limited liability, individual borrowers do not bear the risk of failure (the lenders lose) and this affects their effort. If the effort is increasing the borrowers own wealth, then redistribution towards poor borrowers will have a positive effect on their effort, thus promoting growth. Aghion et al. (1999) argue that redistribution will increase the effort because it reduces borrowing by the poor who now get a larger share of residual output; with a larger share, they have an incentive to work harder.

As is evident, there is a variety of theories suggesting alternative linkages between inequality and growth. Note that most economic theories hinge heavily on one market failure argument or another, and particularly on imperfect capital markets. In a developed-country case, this would only seem to make sense in the context of human capital given well-developed capital markets for other forms of investment in physical capital. If redistribution is to occur, it would have to be financed by distortionary taxes on wages and savings. This would have the traditional negative incentive effects on growth, offset or perhaps overcome by the opportunity-enhancement effect. However, the presumption that the appropriate policy to stimulate growth is to passively redistribute income is far from evident. With inequality of access to investment across individuals, a more suitable policy response would be to either a) reform financial institutions and markets such that able individuals could invest in education, or b) provide more direct support for public education.

The political economy theories point out that one must distinguish carefully between three related factors: inequality, which can be measured before the tax and transfer system apply; redistribution, which is income-based; and social insurance, which is situation-specific. Depending upon the assumptions made, more market income inequality before taxes and transfers may lead to greater or less redistribution *ex post.* Lindbeck views social protection as inducing greater political rent-seeking, whose opportunity cost is growth; the other view of social policy is that it provides insurance in a world with insufficient private markets for insuring risk against sickness, unemployment, and so forth.

Thus, social safety nets a) promote individual investments in human capital and b) reduce political opposition to growth-promoting adjustments and policies. Which of these effects are more important?

In this instance, economic theory points to interesting hypotheses and provides the empirical economist, or policy maker, with some insight on what roadmarks to look for in determining the set of interactions amongst variables. Beyond that, however, the theories themselves are too diverse and too malleable to changes in assumptions or parameter choice to form a basis for reliable policy formulation without empirical validation.

SOCIAL POLICY AND GROWTH EVIDENCE

IT IS ENTIRELY POSSIBLE, AND THEORETICALLY REASONABLE, that social policy might affect growth without a strong effect on the income distribution. For example, many of the theoretical arguments about the consequence of active labour market policies suggest that these could, in principle, be growth-enhancing. These same policies might also reduce the degree of market income inequality, but this is not certain without carefully specifying the dynamic feedback effects from growth to the income distribution. It is however reasonable to ask whether one can empirically identify the linkage between social policy and growth without reference to an intervening effect on inequality. Unfortunately, very few studies have been published on this issue, and it is one on which further research is required. There is a fairly well-developed body of evidence on the effects of government spending on growth, but it generally does not distinguish government spending directed at a social policy objective from spending toward other objectives.[31] A large number of studies on the growth consequences of fiscal policy have documented a significant and negative effect of government consumption on growth.[32]

One innovative study that attempts to look specifically at social policy for OECD countries is Arjona, Ladaique, and Pearson (2001). The authors use a framework similar to that discussed in the section entitled *Some Background: Productivity Growth and Social Policy* to infer the impact of social expenditures on growth in the OECD. The growth equation is a Mankiw-Romer-Weil transitional growth equation that controls for investment and human capital intensity across countries. It is estimated using an annual sample of 21 OECD countries over the period 1970 to 1998. They find virtually no evidence that post tax–transfer inequality affects growth rates in OECD countries. There is some evidence that total government spending on social programs reduces growth. The magnitude of the effects is consequential. In the basic model with aggregate social expenditure as a fraction of GDP, the coefficient is -0.134. This compares with a coefficient on the investment share of 0.345. Both are significant at the 95-percent level.[33] Quantitatively, the implication is that if one were to decrease social spending by 1.0 percent of GDP and increase investment by 1.0 percent of GDP, the impact on aggregate labour productivity growth would be on the order of 0.5 percent per year. Not a large impact, but over a number of years, this would begin to have a significant effect on income levels. Recall that until recently annual labour productivity growth has been in the 1.5 percent range.

The authors do find, however, that when social spending is disaggregated by function the results are cleaner in terms of both significance and magnitude. Passive social spending is prejudicial to growth while active social spending promotes growth. Interestingly, they also find that when the definition of active social spending is expanded to include health expenditures, the coefficient estimates on social spending become insignificant. When they include both passive and active social spending as explanatory variables the coefficient on passive social spending is significant and negative, while the coefficient on active social spending is significant and positive. The orders of magnitude are interesting. The coefficient estimates imply that a shift of 1.0 percent of GDP from passive to active spending produces a positive effect on growth of about 0.5 percent. Overall, the results suggest that social expenditures that promote adjustment and labour market participation tend to increase labour productivity growth, while other forms of social expenditures do not contribute to growth and in fact may reduce it.

Obviously, one should interpret these results with caution given the limited time-series variation in the data and other potentially omitted variables in the growth equation such as R&D and openness. Nevertheless, this is a good start on an important research and policy issue.

An alternative and in many ways unrelated body of evidence links social capital to economic growth. Social capital as defined by Putnam (1993) and Woolcock (1998) refers to the nature of trust in societies engendered by various forms of community association. One of the best known and most representative definitions can be found in the highly influential work of Putnam (1993):

> Social capital ... refers to features of social organisation, such as trust, norms, and networks, that can improve the efficiency of society by facilitating co-ordinated actions.
> (Putnam, 1993, p. 167)

To an economist, as Arrow pointed out long ago, trust is an important substitute for markets and contracts. *A priori*, one would imagine that more trust would imply higher growth. The issue is pertinent to the debate on social policy because there is a strong presumption that social cohesion and social capital are closely related, as argued by Ritzen et al. (2000). A major objective of social policy is to build social cohesion. These authors argue that social cohesion creates an environment in which good policy can be carried out by giving policy makers room to manoeuvre. The latter is created by reducing societal conflict over distributional objectives in part through common institutions such as social policy.

However, the empirical evidence on social trust and growth is simply absent, so there seems to be little point in pursuing in this vein. What evidence exists from cross-country comparisons based on the World Values Survey seems to show that these indices of *trust* actually lead to lower growth (see, for example, Knack and Keefer, 1997). When these authors exclude socialist countries and focus on a more recent period (1980-92), they get stronger results. Controlling for initial income per head, human capital and the relative price of investment goods, an increase of 10 percentage points in the level of their *trust* index (slightly less than one standard deviation) is associated with an annual growth rate higher by 0.8 percentage points. Typically, the results are weaker when attention is restricted to a sample of OECD countries. Also using World Values Survey data, Helliwell (1996) found that trust has a negative effect on growth in a sample of 17 OECD countries. Knack (2000) reports that in a sample of 25 OECD countries, the impact of trust is imprecisely measured, and the hypothesis that it has no effect cannot be rejected at conventional significance levels. This literature may prove to be influential at a future date, but thus far there is little in it that could be used as a major justification for policy.

EXPLAINING RISING INEQUALITY AND FAST GROWTH: THE *NEW ECONOMY* HYPOTHESIS

IF INEQUALITY CANNOT EXPLAIN GROWTH, what about the reverse — does growth causes inequality? We will suggest in this section that the answer to that question is much more interesting from a policy perspective. But providing an exact answer is complicated. In general terms, the answer is sometimes yes and sometimes no. Economic growth in advanced countries is driven by a complex set of interacting factors. However, there is a growing and convincing body of evidence indicating that the recent growth experience of Canada and the United States could be explained by the *new economy* hypothesis — the impact of a major economy-wide technological change attributable to innovations in information technology, computers and telecommunications. The evidence for this is now showing up in the form of accelerated productivity growth in a number of countries, beginning in the United States but also now in Canada. The recognition of this change is now prompting economists to revise their views on recent economic history. The *new economy*, which was in its incipient phase in the early 1980s, has had a number of other important consequences, including increased wage inequality.

NEW ECONOMY: THE GENERAL PURPOSE TECHNOLOGY EXPLANATION

THE HYPOTHESIS STATING THAT THE LAST TWO DECADES was a period where technological change of a particular form has both accelerated and constituted a major shift from the past has come from a variety of theoretical and empirical perspectives. One analytical perspective is that provided by the literature on *general purpose technologies* (GPT) described in Helpman (1998). These are generic and pervasive technologies that transform large sections of the economy, and give rise to widespread complementary investments in physical and human capital, including learning-by-doing. Historical examples include the steam engine, electricity, and the modern manufacturing assembly line method of production. Other accounts, such as that of Greenwood, Hercowitz and Krussell (1997), stress that most of the recent technological change has been embodied in new capital equipment, particularly IT investment-specific technical change (IST). One major piece of evidence in this regard is the dramatic decline in equipment prices over the last two decades. Another perspective is the large literature from labour economics that has attempted to explain wage inequality trends over the past two decades as *skill-biased technological change* (SBT). Each of these perspectives has it own strengths and weaknesses in terms of consistency with the data. Simple SBT theories cannot account for the slowdown and acceleration in growth, while the GPT and IST theories can. The differences between them, however, are less important than their common features. At a popular level, they could all be subsumed under the heading of *new economy* — which is what will be used here.

We now realize that the arrival of the *new economy* was preceded by the demise, in part, of the old economy. This has lead to the obsolescence of skills and industries, which in the short term translates into falling incomes, rising unemployment and a painful structural adjustment that figures prominently in modern Schumpeterian theories of endogenous growth.[34] Economic policy and social policy have been responding to these pressures in predictable ways. The slow growth experienced in the 1970s and 1980s triggered an increase in spending on social support systems and rising debt and deficits. The 1990s led to the realization that the trends in debt accumulation were not sustainable and major fiscal adjustments were adopted in all OECD countries — dramatically so in Canada. These trends may or may not reverse depending upon how the technological transition works through the world economic system. As emphasized by economic historians, there is great uncertainty about the exact consequences of such technological evolutions when you are right in the middle of them.[35] For example, few people realized when it first appeared, or even well after, that a major consequence of the internal combustion engine would be the concentration of population in large cities. Undoubtedly, the same is true for the *new economy*.

The *new economy* hypothesis stresses the causation running from technological change to both growth and inequality. Putting this together with the fact that social expenditure is income-elastic (the Wagner hypothesis) leads to the following interpretation of what has been happening in OECD countries over the last two decades.

1. As the old GPT matures, growth slows down because productivity gains on the old technology become harder to obtain.
2. The GPT *arrives* in the form of a new set of generic technologies, and at first growth slows even more. Measured productivity growth slows down and inequality rises for technological reasons (skilled-biased technological change) and due to the obsolescence effect on older industries and technologies. Social policy responds largely to the increased demand placed upon it by the structural adjustments of the new technology.
3. Growth begins to pick up as productivity gains start to appear with the increased adoption of the new GPT. Wage inequality continues to rise, but pressure for spending on social programs abates as employment and incomes rise.
4. As diffusion of the GPT through the economy begins to peak out, growth slows down slightly but inequality falls due to: a) trickle down effects; b) the factor supply response (more people choose to be educated); and c) less technological displacement. Social spending continues to rise driven by the income effect.

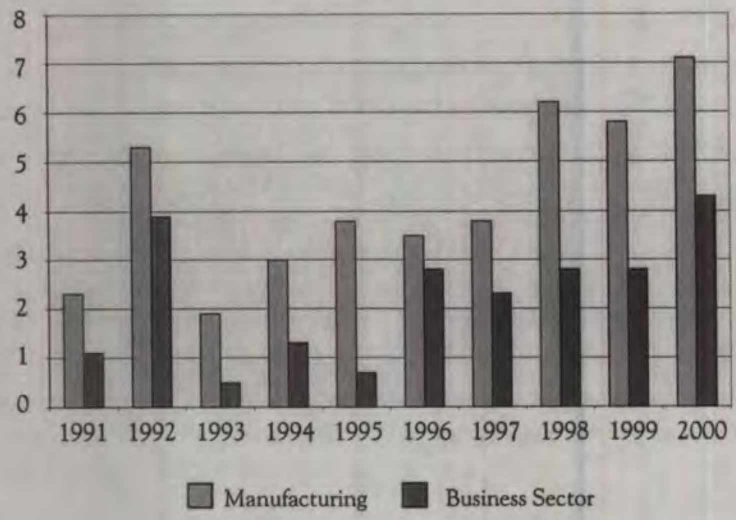
The hope is that we are somewhere in stage 3. Stage 4 is probably some way off.

THE NEW ECONOMY: PRODUCTIVITY EVIDENCE

THE MAJOR PIECE OF MACROECONOMIC EVIDENCE in favour of the *new economy* is the long U.S. economic expansion fuelled by strong and accelerating productivity growth that began in durable manufacturing and is now spreading to the entire business sector. The early productivity gains were almost entirely concentrated in the computer and electronic equipment industries, and the lack of evidence of accelerated productivity growth outside these industries has led to some scepticism as to how widespread these gains might be. As revealed by Figure 3, these gains are considerable, with economy-wide labour productivity growth reaching the 4 percent range by the end of the decade. While the most recent pace of growth is probably not sustainable, the data have suggest that productivity growth in the United States has entered an era of unusually

FIGURE 3

U.S. PRODUCTIVITY GROWTH IN THE 1990S (PERCENTAGE)



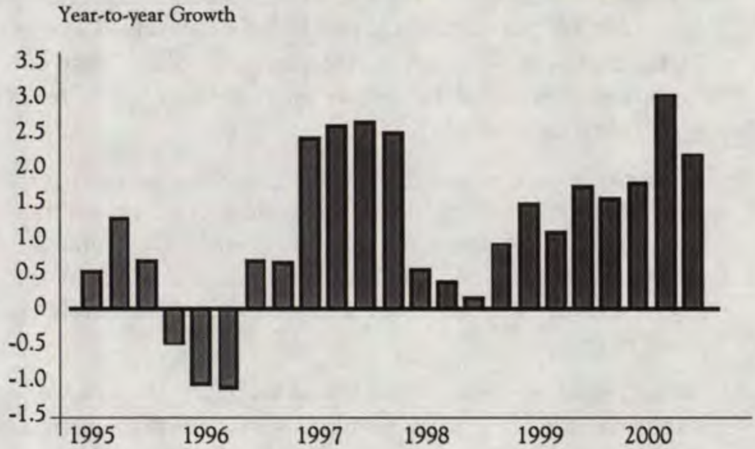
high values. The international dimensions of the *new economy* are yet to be determined. However, the substantial globalization that has taken place over the past decade will probably contribute to a relatively rapid international diffusion by historical standards.

Canada's productivity growth remained quite subdued in the early part of the decade, and even into the mid-1990s there seemed to be little evidence of a *new economy* effect. However, more recent data support the view that the *new economy* is reaching Canada, as shown in Figure 4. Labour productivity in the Canadian business sector grew at an annual pace of 2.1 percent from the third quarter of 1999 to the third quarter of 2000. While this evidence is only suggestive, it does point to trends similar to what happened in the United States.

The acceleration of productivity growth in the late 1990s has generated some controversy as to the quantitative significance of information technologies in fuelling these advances. A recent, and sceptical, summary of the debate linking the *new economy* and the acceleration of productivity is provided by Bosworth and Triplett (2000). The major debate revolves around the fact that IT, principally measured through its capital-deepening effects in a conventional Jorgensonian framework, can only seem to explain about one third of the acceleration in productivity growth. The rest is attributable to growth in TFP — exogenous technical change. The problem with this conclusion is that

FIGURE 4

LABOUR PRODUCTIVITY GROWTH IN THE CANADIAN BUSINESS SECTOR, 1995-Q1 TO 2000-Q3



Source: Statistics Canada website.

the neoclassical production function model underlying the construction of the TFP measurement is least likely to work when technological change is embedded in a GPT. During these transitions, as emphasized in related theoretical and historical work, disentangling TFP growth from the consequences of developing new capital goods is conceptually impossible.[36] Changes in labour productivity, which is what drives economic growth, is the only productivity measure in these circumstances that has an unambiguous intrepretation.[37] IT investments are undoubtedly a manifestation of the broader ICT revolution, but only partly so. The dollar value of IT investments does not tell us anything about the way in which the distribution system is transformed by technological changes.

THE NEW ECONOMY: WAGE INEQUALITY

THE EVIDENCE ON WAGE INEQUALITY plays a major role in understanding this complex set of phenomena. There is a large literature on this issue, and to review it adequately would take us far from the basic object of this paper. Recent surveys include Acemoglu (2000), Gottschalk and Smeeding (1997), Johnson (1997) and Katz and Autor (2000). The data on wage inequality reveal three major facts that seem to be common to number of OECD countries, but particularly Canada, the United States, Germany and the United Kingdom:

1. A slowdown in average real wage growth, which corresponds to a slowdown in measured average labour productivity. The orders of magnitude are considerable, particularly for low-skilled workers. In the United States, workers at the 10th percentile of the wage distribution (i.e. low-skill workers) have seen their earnings fall in real terms to levels below those of 1963.[38]

2. There has been a substantial increase in the education premium for more highly educated workers. The college premium — the wages of college graduates relative to the wages of high school graduates — increased by over 25 percent between 1979 and 1995 in the United States. Canada has witnessed a smaller but qualitatively similar increase in skill premiums.

3. Overall, earnings inequality increased sharply. In 1971, a worker at the 90th percentile of the wage distribution earned 266 percent more than a worker at the 10th percentile. By 1995, this number had risen to 366 percent.[39] A substantial part of this increase in inequality is not explained by education but by some unknown factor. When controlling for education, experience and other variables, there is a remarkable increase in measured within-group or residual wage inequality. Many studies point to an rise in wage inequality of up to 60 percent within groups who have apparently the same education and age.

The trends in Canada have been similar but with some differences. Murphy, Riddell and Romer (1998) note that part of the Canada-U.S. differences in skill premiums can be accounted for by the relatively larger increase in the supply of educated workers in Canada over the last two decades. Also, the productivity evidence suggests that the new GPT was entering Canada at a somewhat slower pace than in the United States. There is no precise way one can yet prove this, but one piece of supporting evidence is the relatively lower rate of IT investment in Canada than in the United States during the 1990s.[40] Recently, Beaudry and Green (1999) have put forward an alternative explanation of the OECD wage inequality trends, based on the arrival of a GPT characterized by a higher capital-labour intensity together with differences in the cost of capital across countries. While leading to slightly different implications, specifically with respect to the key role of investment, the general thrust of their results is consistent with other *new economy* theories.

Explaining the slowdown in measured productivity at the same time that technological change was accelerating has been attempted in a large number of theoretical papers, including Acemoglu (2000), Helpman and Trajtenberg (1998), Greenwood and Yorukoglu (1997), Hornstein and Krusell (1997) and Galor and Moav (2000). The theories all have a similar mechanism that involves a new technology slowly displacing an old technology. However, the new technology requires substantial learning-by-doing and investment in complementary skills and equipment. All of this, together with the obsolescence of the old technology, leads to a sustained period of slow to negative productivity growth. The slow growth in wages, particularly of unskilled workers, is a reflection of these factors. This theory may even *explain* part of the famous productivity slowdown of the mid-1970s. Moreover, a similar reasoning can be used to explain why the growth performance of a number of countries has differed from that of the United States due to lags in adoption. The slow growth in the United States during the 1980s is indicative of the type of productivity growth that is likely to be felt as the GPT hits the economy.

The general view of the current ICT-driven GPT is that it increases the returns to skills and leads to an increase in within-group wage inequality. There are a number of ways in which the GPT raises the returns to skills, but one of the simplest mechanisms is capital-skill complementary, as first argued by Nelson and Phelps (1966). One major historical GPT that has received a considerable amount of research attention is electricity. Goldin and Katz (1998) provide strong evidence of technology-skill complementarity during the 1910s and 1920s due to the increased demand for skills coming from the introduction of electricity in most manufacturing processes. This view of technological change is similar to that put forward today with respect to ICT innovations. The current GPT is a type of technological change inherently biased towards skilled workers, given that the skills required are complementary to the new capital goods. Collectively, the skill–capital mix tends to displace unskilled workers.

Explaining higher within-group inequality can be done by appealing to the interaction between education and learning-by-doing (LBD) on the new GPT. Aghion et al. (1999), for example, argue that with vintage-specific skills and vintage-specific LBD we get an increase in within-group inequality as the new GPT arrives. Workers choose between staying on old machines or moving to new machines and start LBD all over. When the rate of embodied technological progress rises, there is a greater heterogeneity in outcomes, as those choosing to move to the new technology are lucking out with higher *ex post* returns.[41] This within-group effect should begin to dissipate over time as the new technology embodied in the GPT becomes pervasive. However, the lags involved could be very long. Older workers in particular are those most likely to be adversely affected no matter what their skill level on the old GPT.

If the GPT view of wage inequality is correct, there is the distinct possibility that market wage inequality will fall as the GPT matures. There is some evidence in the United States that this is now happening, as witnessed by recent wage increases in traditional low-skilled service industries. The markets for human capital respond by increasing the supply of those skills that are particularly scarce. In addition, there are usually trickle down effects across the skill spectrum. Both of these factors tend to reduce inequality.

THE *NEW ECONOMY*: POLICY IMPLICATIONS

THE IMPLICATIONS FOR THE LINK BETWEEN SOCIAL POLICY AND PRODUCTIVITY are considerable. First, the *new economy* perspective provides a coherent explanation of both growth and inequality trends as endogenous reactions to a common cause — an acceleration in the rate of technological change. The good news is that these effects are highly non-linear in time. As the *new economy* matures and diffuses, productivity growth increases. What will happen to wage inequality in the future will have a major influence on the future course of social policy, human capital policy and, more generally, on income inequality. At this point we can only hope that high rates of economic growth will tend to *raise all boats* and that, in the long run, income inequality will fall.

Over the very long term, social and economic policy is part of a set of framework policies that condition how a national economy will respond to global technological forces. Judging the relative merits of alternative policies in terms of a productivity payout, or the cost-benefit ratio on an additional dollar spent in a particular form of program, will depend critically on the extent to which each policy will facilitate the medium-term structural adjustment to these technological changes.

CONCLUSIONS

THE LINKAGES BETWEEN ECONOMIC GROWTH AND PRODUCTIVITY are both complex and subject to a variety of potential causal mechanisms. This paper has reviewed the evidence and theory linking the social determinants of productivity growth and contrasted these with more conventional economic determinants such as investment and innovation. The social determinants include such factors as the distribution of income and wealth in society, the set of social policies existing in a country, including social insurance and redistributive programs, the education and health systems, and the degree of social cohesion. The complexity in uncovering a link running from social factors to productivity growth is compounded by the fact that these broad institutional arrangements, including the social determinants but also the political and legal systems, may have indirect effects in the long run that are difficult if not impossible to detect in conventional economic data. In spite of these problems, there is a new body of research, both theoretical and empirical, that attempts to identify the relationship between social policies, economic inequalities and productivity growth.

The traditional economic debate on these matters was usually framed in terms of the equity–efficiency tradeoff, in which more economic growth could only be obtained at the expense of increased economic inequality. The newer literature suggests that, in fact, growth and social objectives may be complements rather than substitutes. This certainly provides a more optimistic view of the choices facing governments than has been the case based on the existence of a growth–equity tradeoff.

While these recent empirical and theoretical contributions are interesting and suggest some important new areas for research, it is premature to assume that this literature proves a robust linkage running from social policy and inequality to productivity growth. One cannot conclude that reduced income inequality leads to increased productivity growth, or that more social spending leads to increased productivity growth. The empirical evidence establishing such a linkage, which at this point is largely based on macroeconomic cross-country comparisons, is simply either not in the data, or statistically fragile. Moreover, much of what has been offered as evidence in favour of this hypothesis rests on developing-country data, which is of questionable relevance to an advanced industrial country like Canada. It is important to emphasize the recent origins of this research. Virtually all of it has been done in the last ten years, and the total number of studies is still quite limited. It is possible, therefore, that our views based on the weight of evidence will change in the next few years. The one major exception to these observations concerns education. There is a very large body of evidence showing that increasing education has a substantial effect on productivity. The role of human capital in Canada's economic growth has been an enduring theme of both social and economic policy. The evidence surveyed in this paper provides a strong endorsement of this view. For example, Tom Courchene in his recent book *A State of Minds: Toward a Human Capital Future for Canadians* (2001), comes to very similar conclusions but from a different perspective. The evidence on health expenditures is less convincing, but in general the productivity case for improving human capital is compelling and requires further research.

The paper also discusses other research linking the economic determinants of productivity and the consequences of major technological change for both inequality and growth. This very recent literature associated with the *new economy* hypothesis carries some potentially interesting implications for both social and economic policy, in that it offers a coherent explanation of why inequality rose and growth slowed during the 1975-95 period, and why there is now an apparent acceleration of productivity. If this view is correct, it also offers some potential clues as to the future pressures on wage inequality and their consequences for social policy.

In summary, the major conclusions of the paper are as follows:

1. The general case linking social policies or inequality to productivity growth remains unproven. Justification for any particular social policy innovation must rest on its cost-effectiveness in reaching its stated social goals. What little evidence we have suggests that social policies promoting labour market participation, rather than passive cash-transfer programs, are most likely to generate productivity benefits, although the magnitude of the effects remains uncertain. A great deal more research is necessary to link social policies to productivity, particularly at the micro level, before a productivity argument could to be used to promote a particular social policy.

2. Policies that have been proven to most likely increase productivity are those focused on the proximate economic levers to productivity growth — those that stimulate investment, innovation and competition, and facilitate the international diffusion of knowledge.

3. The one social policy for which there is ample evidence of positive productivity effects is education. A substantial portion of Canada's economic growth appears to be attributable to the country's high levels of educational attainment.

4. The *new economy* perspective provides a coherent explanation of both recent growth and inequality trends as endogenous reactions to a common cause — the acceleration of technological change. The growing evidence linking both recent and past productivity data, together with evidence on wage inequality trends in industrial countries, provides a more coherent perspective from which to assess policies linking productivity and inequality. A growth-oriented policy must both promote technological adaptation through investment and skill acquisition, and facilitate the required structural change across regions, industries, firms and workers. Social policy can help facilitate these adjustments by providing the least well-off with the necessary resources to make the required investments in human capital both for themselves and for their children.

The major rationale underlying social policies in the modern mixed economy has never been higher productivity growth. The general concerns for social justice, and the political demands of an increasingly wealthy society for improved education, health and social insurance have long been the major reasons voters have requested these policies in Canada. This will undoubtedly continue to be true provided economic growth is sustained. Failure to increase or keep pace with living standards in other advanced countries is ultimately the most serious threat to Canada's social programs. In that sense, productivity issues and social policy will always be linked.

ENDNOTES

1 For a recent review of these arguments in a Canadian perspective, see Osberg (1995).
2 Krugman (1994) provides a very readable statement of this argument.
3 See Lindbeck (1975, 1985).
4 Also referred to as endogenous growth theory. Surveys of this field are presented in Aghion and Howitt (1998) and Jones (1999).
5 On aging and social security reform, see OECD (1998). The literature subsequent to the *OECD Jobs Study* is voluminous. A review is provided by Disney (2000).
6 This section draws on material in Harris (1999).
7 For a brief and non-technical review of productivity measurement, see Harris (1999). For an extensive review of the literature and a history of the subject, see Hulten (2000).
8 In the Canadian data, the majority of productivity growth is accounted for by TFP growth or multifactor productivity (MFP) growth. MFP growth data are published regularly by Statistics Canada.
9 A good example is Mokyr (1990).
10 For a recent survey, see Ritzen, Easterley and Woolcock (2000).
11 See Levine and Renelt (1992) and Sala-i-Martin (1997).
12 For the non-OECD sample, the model was actually somewhat more successful, although this result has been criticized on a number of fronts.
13 See Temple (1999).
14 These models almost always ignore adjustment costs, which is a serious problem in using them for welfare evaluations. With high adjustment costs, fast convergence is not always a good thing.
15 Both are covered in greater detail in the section entitled *The Human Capital Dimension of Growth*.
16 See, for example, Benhabib and Spiegel (1994).
17 See Mokyr (1990), for example.
18 It is also consistent with other comparative international micro-based evidence. For example, for education beyond the 8th year, a value of 6.8 percent was estimated for the OECD.
19 The results of this study were subsequently reversed by a number of authors. See Acemoglu and Angrist (1999), for example.
20 There also is an active critique of the human capital literature based on the well-known signalling argument — education does not add to productivity, but in a

world of imperfect information it signals to employers those who have higher ability. Virtually all of the literature referred to above ignores this issue. See Weiss (1995) for further discussion.

21 On East Asia, see Young (1995), and on Ireland, see Barry (1999).

22 Fogel (2000) pp. 1-21.

23 An increases in the Gini coefficient corresponds to an increase in inequality.

24 Beach and Slotsve (1996) document these trends for Canada.

25 A survey of this literature is provided in Benabou (1996).

26 Contributions to the analysis of growth using panel data sets and fixed-effects estimation include Barro and Lee (1994), and Barro and Sala-i-Martin (1995).

27 An exception is Perotti (1996) who looks at the effect of inequality on female education and fertility for developing countries and finds a significant effect. This suggests that it may be the important causal channel in developing country data.

28 See Levine and Renelt (1992) and Sala-i-Martin (1997).

29 For a comprehensive survey, see Aghion and Howitt (1998).

30 Aghion, Caroli and Garcia-Penalosa claim that this is inconsistent with evidence showing that redistribution has a positive effect on growth and that measures of redistribution are uncorrelated with inequality — they cite Perotti (1994) whose Tables 4 and 8 report regression results. The measure of redistribution is the marginal tax rate.

31 There are a few older studies that claim to focus on the links between social expenditure and growth. Unfortunately, they rely on the cross-sectional approach and most suffer from data deficiencies. Results have generally been mixed, but most come to the conclusion that social expenditure is bad for growth. See, for example, Landau (1985), Gwartney, Lawson and Holcombe (1998), Hansson and Henrekson (1994), Lindert (1996) and Weede (1986, 1991).

32 This is the literature on fiscal policy and growth. A modern example is Easterly and Rebelo (1993). Temple (1999) covers the evidence in his survey.

33 Results reported in Table 6.4, column 2.

34 This class of theories is a major focus of Aghion and Howitt (1998). The Schumpeterian perspective gives prominence to the process of creative destruction that technological change leads to.

35 See Lipsey, Bekar and Carlaw (1998) for a discussion of the uncertainty surrounding GPT transitions.

36 In one of the early theoretical GPT papers, Helpman and Trajtenberg (1998) noted that the diffusion of a GPT would lead to an acceleration in conventionally measured TFP. However, the cause of that acceleration lies with the adoption and diffusion of the GPT itself.

37 Even this conclusion has to be qualified if output cannot be measured correctly. For example, labour productivity statistics in service industries are thought to be unreliable because of the inability to measure quality changes in their output. This problem does not, however, undermine the evidence on productivity acceleration. The service measurement problems have been present for a number of decades.

38 This is a summary of Acemoglu (2000) on the U.S. wage evidence.

39 From Acemoglu (2000).

40 Schreyer (1999) calculates that, from 1990 to 1996, ICT contributed 0.26 percentage points to the average 1.30 percent labour productivity growth. For the United States, he calculates that ICT account for 0.41 percentage points of the average 1.0 percent labour productivity growth. Note that this data predates the acceleration phase referred to earlier.

41 Note that in this framework, increased education or training — if it facilitates greater mobility across vintages — will tend to reduce wage inequality, thus offsetting in part the growth effect of the GPT on inequality.

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25

The Contribution of Productivity to Economic Well-being in Canada

IT IS WELL ESTABLISHED THAT PRODUCTIVITY IS THE KEY DRIVER of living standards, as measured by income per capita in the long run. The objective of this paper is to broaden the focus of the debate from the link between productivity and income to that between productivity and economic well-being. Indeed, the paper argues that productivity is almost as important for determining the economic well-being of Canadians as it can be for determining their income.

In this paper, we lay out a framework for analyzing the two-way or bi-directional relationship between productivity and economic well-being, defined in terms of the four components of the Index of Economic Well-being developed by the Centre for the Study of Living Standards (CSLS).[1] The effects of productivity gains for the different components of economic well-being are explored at a conceptual level and in the context of Canada's post-war growth experience. The implications for productivity of independent improvements in the four components of economic well-being are then discussed.

Productivity growth is the most important source of long-term economic growth. From 1946 to 2000, growth in real GDP per hour accounted for 65 percent of real GDP output growth in the business sector in Canada, with growth in total hours worked providing the remaining 35 percent. From this perspective, the impact of productivity on economic well-being is not identical to the impact of economic growth (productivity and labour input) on economic well-being. In certain instances, increased productivity may have different effects on economic well-being than an increase in employment or hours worked. Nevertheless, the overall impacts are very similar because productivity accounts for such a large proportion of economic growth and because both productivity and labour input increase real income and the tax base.

THE CSLS INDEX OF ECONOMIC WELL-BEING

THE FOUR COMPONENTS OR DIMENSIONS of economic well-being in the Index of Economic Well-being developed by the Centre for the Study of Living Standards are the following:

- Effective per capita consumption flows, which include consumption of private and public goods and services, and effective per capita flows of household production, leisure and other unmarketed goods and services;
- Net societal accumulation of stocks of productive resources, including net accumulation of tangible capital, the housing stock, net accumulation of human capital, the research and development (R&D) capital stock, net changes in the value of natural resources stocks; the cost of environmental degradation, and the net change in the level of foreign indebtedness;
- Poverty and inequality, which include the intensity of poverty (incidence and depth) and the inequality of income; and
- Economic insecurity from job loss and unemployment, illness, family breakup and poverty in old age.

A detailed discussion of the rationale for the inclusion of the above variables, and the manner in which they have been included in the Index of Economic Well-being is provided in Osberg (1985) and Osberg and Sharpe (1998).

Table 1 and Figure 1 provide estimates of the four components of the Index of Economic Well-being for Canada from 1971 to 1999. The largest increase was experienced by the per capita consumption flows, up 46.9 percent, followed by wealth stocks (38.6 percent) and equality (7.6 percent). In contrast, economic security fell 25.6 percent, with all the decline taking place in the 1990s.

A key aspect of the Index is the weighting scheme applied to the four basic components as different weights produce different results.[2] The weights are subjective and reflect one's judgment about the relative importance of the components. In the most recent version of the Index, equal weights have been used. This weighting scheme has been found the most effective for the presentation of the Index. Table 1 and Figure 2 show that, based on the equal weighting scheme, the Index of Economic Well-being advanced only 16.6 percent in Canada from 1971 to 1999. The decline in economic security and the small increase in equality hampered the growth of the overall Index. An alternative weighting scheme that gives greater weight to consumption (0.7) and less to the other three components (0.1 each) shows a larger increase (34.8 percent).

TABLE 1

INDEX OF ECONOMIC WELL-BEING FOR CANADA, 1971-99

	Components of Well-being				Total Index		
	Adjusted Total Consumption	Wealth Stocks	Equality Measures	Economic Security	Equal Weighting	Alternative Weighting	GDP per Capita
1971	1.000	1.000	1.0000	1.0000	1.0000	1.0000	1.0000
1972	1.030	0.999	1.0034	1.2160	1.0620	1.0427	1.0322
1973	1.087	1.020	1.0034	1.2895	1.1001	1.0923	1.0937
1974	1.143	1.053	1.0028	1.2781	1.1193	1.1334	1.1230
1975	1.189	1.073	0.9982	1.1910	1.1128	1.1585	1.1309
1976	1.213	1.093	1.0415	1.0882	1.1088	1.1711	1.1774
1977	1.239	1.109	0.9447	0.9790	1.0681	1.1709	1.2038
1978	1.249	1.128	0.9650	0.9871	1.0823	1.1824	1.2399
1979	1.259	1.188	0.9963	0.9235	1.0919	1.1924	1.2797
1980	1.279	1.260	1.0573	0.9408	1.1342	1.2209	1.2810
1981	1.272	1.226	1.1224	0.9553	1.1439	1.2208	1.3259
1982	1.255	1.223	1.1188	0.9734	1.1426	1.2102	1.2729
1983	1.273	1.255	1.1112	0.9652	1.1508	1.2239	1.2944
1984	1.295	1.256	1.0487	0.9769	1.1442	1.2350	1.3569
1985	1.338	1.242	1.1075	0.9846	1.1680	1.2700	1.4080
1986	1.349	1.186	1.1553	0.9592	1.1622	1.2741	1.4280
1987	1.372	1.210	1.1532	0.8810	1.1542	1.2851	1.4698
1988	1.408	1.236	1.1836	0.9945	1.2056	1.3272	1.5219
1989	1.427	1.250	1.2291	1.0566	1.2408	1.3526	1.5344

TABLE 1 (CONT'D)

	COMPONENTS OF WELL-BEING				TOTAL INDEX		
	ADJUSTED TOTAL CONSUMPTION	WEALTH STOCKS	EQUALITY MEASURES	ECONOMIC SECURITY	EQUAL WEIGHTING	ALTERNATIVE WEIGHTING	GDP PER CAPITA
1990	1.429	1.266	1.1813	1.0208	1.2244	1.3474	1.5142
1991	1.410	1.240	1.1789	0.9726	1.2005	1.3261	1.4635
1992	1.422	1.234	1.1725	0.9317	1.1900	1.3292	1.4584
1993	1.417	1.233	1.1946	0.9071	1.1880	1.3253	1.4755
1994	1.415	1.253	1.1928	0.8454	1.1765	1.3195	1.5278
1995	1.414	1.281	1.1524	0.7929	1.1601	1.3127	1.5537
1996	1.417	1.321	1.0998	0.7347	1.1429	1.3071	1.5611
1997	1.431	1.353	1.0778	0.7324	1.1486	1.3182	1.6111
1998	1.451	1.363	1.0758	0.7301	1.1548	1.3324	1.6595
1999	1.469	1.386	1.0758	0.7341	1.1663	1.3479	1.7296

Note: Equal Weighting = 0.25*Consumption + 0.25*Wealth + 0.25*Equality + 0.25*Security.
Alternative Weighting = 0.7*Consumption + 0.1*Wealth + 0.1*Equality + 0.1*Security.
Source: Centre for the Study of Living Standards, 2002.

TABLE 2

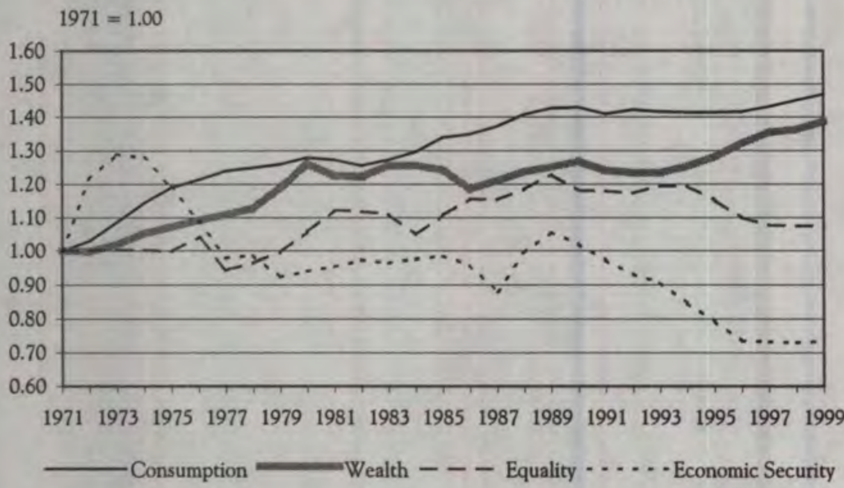
TRENDS IN LABOUR PRODUCTIVITY AND REAL WAGES, 1961-2000

	Average Annual Rate of Change			
	1946-2000		1961-2000	
	Output per Hour	Consumer Real Wage	Output per Hour	Consumer Real Wage
Business Sector	2.63	2.31	2.00	1.62
Agriculture	4.37	2.35	4.36	1.46
Manufacturing	3.06	2.23	2.74	1.60
Fishing and Trapping	–	–	-0.17	1.67
Logging and Forestry	–	–	2.21	2.44
Mining, Quarrying, and Oil Wells	–	–	1.64	2.25
Construction	–	–	0.78	1.32
Transportation and Storage	–	–	2.43	1.17
Communication and other Utility Industries	–	–	3.40	1.31
Wholesale Trade	–	–	2.49	1.62
Retail Trade	–	–	2.12	0.91

Source: Statistics Canada, *Aggregate Productivity Measures*, May 28, 2001.

FIGURE 1

COMPONENTS OF THE INDEX OF ECONOMIC WELL-BEING FOR CANADA, 1971-99



Source: Centre for the Study of Living Standards, 2002.

GDP per capita in Canada rose 73.0 percent between 1971 and 1999 (see Table 1 and Figure 2), which is significantly more than the Index of Economic Well-being, whether based on an equal weighting or consumption-biased weighting scheme. The greater the weight given to consumption, however, the closer trends in the Index approach trends in GDP per capita.

THE IMPACT OF PRODUCTIVITY ON ECONOMIC WELL-BEING

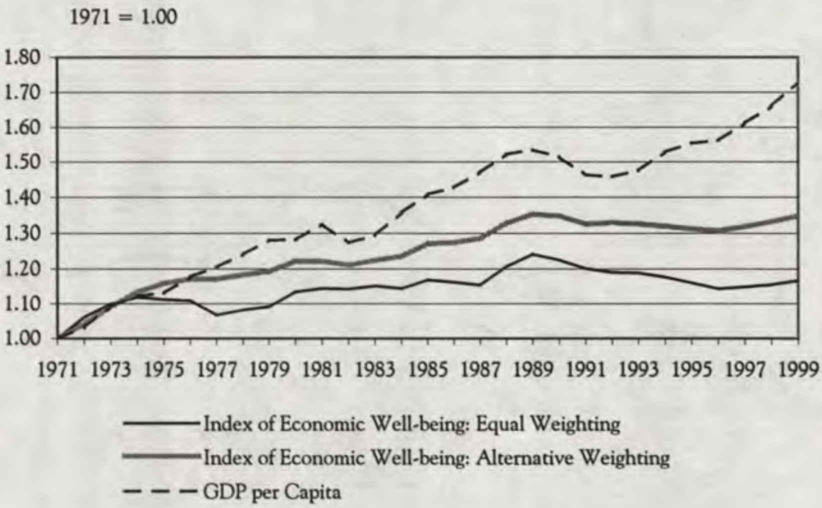
THIS SECTION EXPLORES THE IMPACT OF PRODUCTIVITY for the consumption, stocks of wealth, inequality, and economic security components of the Index of Economic Well-being.

CONSUMPTION

THE CONCEPT OF CONSUMPTION FLOWS USED in the Index includes private and public consumption and unpaid work, and makes adjustments for a number of factors, including life expectancy, household size, regrettables or negative

FIGURE 2

TRENDS IN ECONOMIC WELL-BEING, AND GDP PER CAPITA IN CANADA, 1971-99



Source: Centre for the Study of Living Standards, 2002.

externalities (cost of commuting, crime, auto accidents, and pollution abatement) as well as changes in working time.

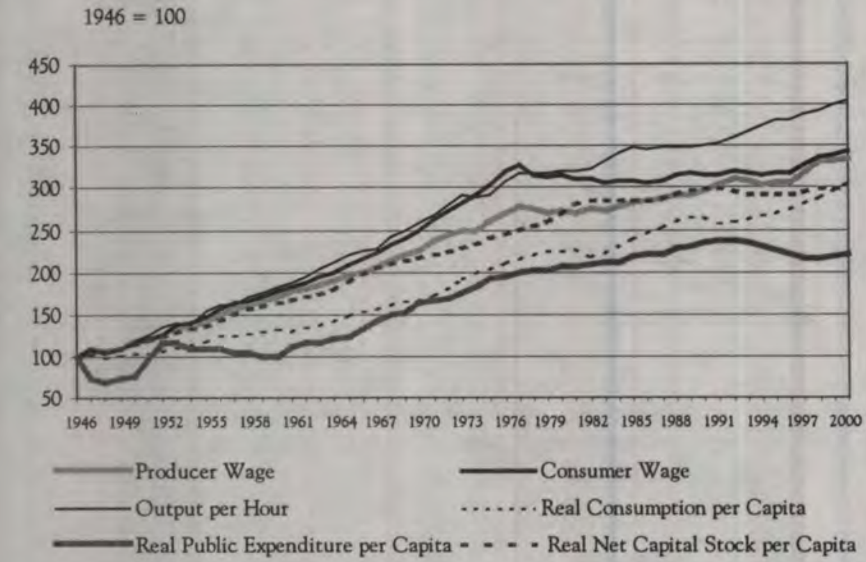
Private Consumption

The basic relationship between productivity and consumption is that productivity growth raises output and income, and income is the key determinant of consumption. Productivity increases real income, and when people earn more, they spend and consume more. Of course, not all increases (in either an absolute or proportionate sense) in income arising from productivity gains are spent. A significant proportion is taxed away by government, reducing potential private consumption, but possibly increasing public or collective forms of consumption and positively affecting the other components of economic well-being. A portion is also saved, and goes toward financing investment.

The relationship between changes in productivity and changes in marketed consumption or the private component of total consumption thus flows through real wage gains. At the aggregate level, increased levels of output per hour over long periods of time translate into higher real labour compensation

FIGURE 3

INDEX OF REAL WAGES, PRODUCTIVITY AND CONSUMPTION IN THE BUSINESS SECTOR, 1946-2000



Source: Statistics Canada, *Aggregate Productivity Measures*, May 28, 2001, *National Accounts*, and *Historical Statistics of Canada*.

per hour, as labour's share of national income has tended to remain relatively constant over time.[3] Growth in real labour compensation or income in turn fuels the growth of private consumption.

For example, over the 1946-2000 period, business sector output per hour increased an average 2.63 percent per year in Canada, while real hourly labour compensation deflated by the Consumer Price Index (CPI) — known as the consumer wage — rose 2.31 percent, and deflated by the GDP deflator — known as the producer wage — rose 2.06 percent (Table 3).[4] In absolute terms, productivity increased 305.4 percent, or more than quadrupled over the 54 years going from 1946 to 2000. The real consumer wage rose 242.6 percent and the producer wage 233.7 percent (Figure 3). The discrepancy reflects the fact that the business sector represents less than 80 percent of the economy. Productivity growth in the non-business sector is much lower than in the business sector, reducing aggregate or total economy productivity growth and bringing it closer to real wage growth.

TABLE 3

PRODUCTIVITY TRENDS IN THE BUSINESS SECTOR IN CANADA, 1946-2000

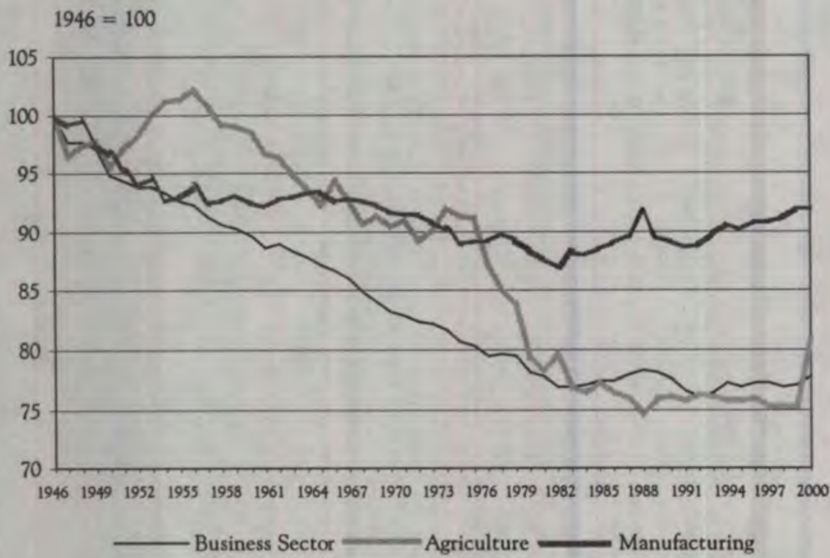
Average Annual Growth Rates	Real GDP	Number of Jobs	Average Weekly Hours	Total Hours Worked	Labour Compensation per Worker	Real GDP per Hour	Total Labour Compensation	Hourly Labour Compensation	Unit Labour Cost	Real Consumer Wage	Real Producer Wage	Real Consumption per Capita	Real Public Expenditure per Capita	Real Net Capital Stock per Capita
1946-1973	5.05	1.72	-0.73	0.98	6.72	4.03	8.52	7.51	3.38	3.90	3.42	2.43	2.08	3.09
1973-1981	3.25	2.71	-0.66	2.04	10.38	1.18	13.42	11.09	9.79	1.28	1.13	2.15	2.14	2.63
1981-1989	3.18	1.97	0.04	2.02	5.57	1.13	7.63	5.52	4.35	0.22	0.94	2.03	1.29	0.66
1989-2000	2.74	1.40	-0.04	1.36	2.92	1.37	4.37	2.97	1.58	0.71	1.21	1.24	-0.35	0.16
1946-2000	4.03	1.84	-0.46	1.37	6.29	2.63	8.24	6.79	4.08	2.31	2.26	2.09	1.48	2.06
1973-2000	3.02	1.96	-0.20	1.76	5.87	1.24	7.95	6.08	4.78	0.73	1.10	1.74	0.87	1.04

Note: The growth rate of the number of jobs plus the growth rate of average hours gives the growth rate of hours worked. The growth rate of hours worked plus the growth rate of hourly compensation gives the growth rate of total compensation. The growth rate of real GDP minus the growth rate of hours worked gives the growth rate of real GDP per hour. The growth rate of total compensation minus the growth rate of real GDP gives the growth rate of unit labour cost. The real consumer wage is defined as hourly compensation deflated by CPI, and the real producer wage is defined as hourly compensation deflated by the GDP deflator.

Source: Statistics Canada, *Aggregate Productivity Measures*, May 28, 2001; GDP deflator and data on real consumption per capita are taken from the *National Accounts* and *Historical Statistics of Canada*; CPI data are taken from CANSIM.

FIGURE 4

INDEX OF AVERAGE WEEKLY HOURS WORKED, 1946-2000



Source: Statistics Canada, *Aggregate Productivity Measures*, May 28, 2001.

Productivity growth slowed precipitously after 1973, falling from 4.03 percent per year in the 1946-73 period to 1.24 percent from 1973 to 2000. This weak productivity growth meant that real wage growth warranted by productivity gains was now much less. Indeed, the rate of increase in the real consumer wage fell to 0.73 percent per year during 1973-2000, from 3.90 percent during 1946-1973.

This close long-run relationship or correlation between real wages and productivity reflects the fact that real wage growth in an accounting sense is limited by increases in the amount of output produced per hour worked. Changes in capital's and labour's share of output can result in divergences between productivity and real growth over short periods, as seen in Figure 3 during the early 1970s when consumer wage growth briefly exceeded productivity growth. But over long periods, factor shares have been relatively stable and so they had little effect on real wage growth.

The primary causal linkage in the productivity–real wage relationship runs from increased productivity to higher real wages. Nevertheless, there can also be a causal linkage running from wages to productivity. For example, a large increase in wages can have a positive effect on labour productivity through greater substitution of capital for labour. In this sense, productivity and real wages are both endogenous variables.

The relationship between real wages and consumption is mediated by the tax and transfer system and the saving behaviour. Only part of labour income is spent on consumer goods, with the rest going to savings and taxes. Reciprocally, consumer spending is financed by transfer payments and investment income from savings.

Real consumption per capita advanced 205.6 percent or 2.09 percent per year over the 1946-2000 period (Table 3 and Figure 3). Real wage gains, fuelled by productivity growth, thus exceeded per capita consumption growth. As noted above, real wage gains do not translate one-to-one into consumption growth because of savings and the growing tax burden. Equally, real consumption growth has been affected by changes in the ratio of employment to the total population, which is determined by the demographic structure of the population (an increasing share of the total population in the non-working age group up to 1980, and in the working age group — 15 and over — after 1980 caused by the birth and aging of the baby-boom cohorts), as well as by the participation rate and the unemployment rate. Consumption is also financed by non-wage income from investment, transfer payments and other sources, and by consumer debt. The role of government transfers in financing consumption has increased greatly over time, from 6.6 percent of personal income in 1947 to a peak of 15.5 percent in 1991, before declining to 13.6 percent by 2000 (Figure 5A and 5B).

The long-run relationship between aggregate productivity and real wage growth does not hold on an industry or sector basis. For example, Table 2 shows that for ten sectors in Canada over the 1961-2000 period, there was much greater variance in productivity growth than in real wage growth. The range for sectoral productivity growth was 4.5 percentage points per year, from a low of -0.17 percent per year in fishing and trapping to a high of 4.36 percent in agriculture. In contrast, the range for sectoral real wage growth was only 1.5 percentage points, from a low of 0.91 percent in retail trade to a high of 2.44 percent in logging and forestry.

FIGURE 5A

GOVERNMENT TRANSFER PAYMENTS TO PERSONS AS A PERCENTAGE OF PERSONAL INCOME, 1947-2000

Source: Statistics Canada, *National Accounts*.

The competitive nature of the labour market and the wage determination process tend to put downward pressure on, if not eliminate, divergences in labour compensation increases across industries, *ceteris paribus*. This explains the relatively limited range of sectoral real wage growth. Industries with above average productivity gains such as agriculture and communications have seen the relative price of their output fall, while sectors with below average gains such as personal services have seen their relative prices rise.

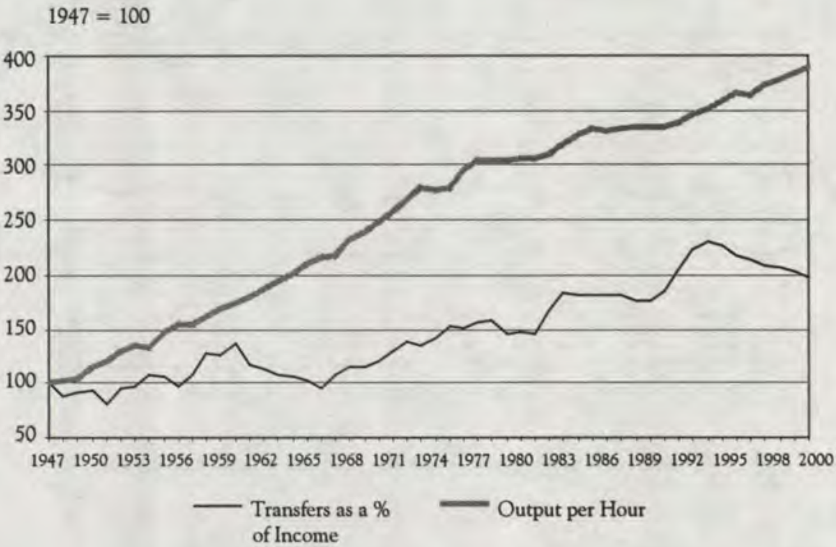
This aggregate relationship is also consistent with increases or decreases in earnings or wage inequality, as such changes merely redistribute income among workers and do not affect labour's share of national income. If this long-term relationship had not held and labour productivity growth had exceeded real labour compensation gains, the share of labour in national income would have declined and that of profits would have increased, which has not happened.

Changes in Non-working Time or Leisure

The relationship between productivity gains and changes in non-working time or leisure is more complex than the relationship between productivity and private and public consumption. From a theoretical perspective, productivity growth gives individuals greater choice in the leisure/work tradeoff. Three options are possible. With increased productivity, individuals can choose to use all productivity gains for increased leisure, foregoing any increase in income.

FIGURE 5B

PRODUCTIVITY AND GOVERNMENT TRANSFER PAYMENTS TO PERSONS AS A PERCENTAGE OF PERSONAL INCOME, 1947-2000



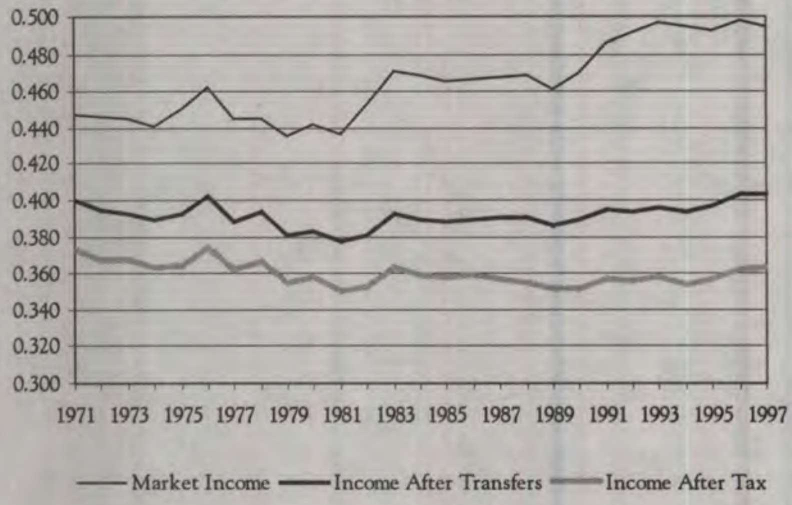
Source: Statistics Canada, *National Accounts* and *Aggregate Productivity Measures*, May 28, 2001; and Department of Finance, *Quarterly Economic Review*, June 1991.

If productivity doubles, everyone could work one half of the hours currently worked yet still enjoy the same real income level. Second, individuals can use productivity gains for both increased leisure and income. Third, individuals can forgo all reductions in working time and use all productivity gains for increased income.

Average annual hours actually worked for the employed population is determined by the length of the average work week (hours per day and days per week) for full and part-time workers, the mix of full and part-time workers, and the number of weeks worked per year, which is affected by the incidence of part-year work, vacation time, statutory holidays, educational leave, sickness leave, etc. Average annual hours worked per working-age person is determined by average annual hours worked per employed person and the employment rate. This latter variable is in turn determined by a number of other factors, including the unemployment rate, the age structure of the population, and the labour force participation rate (itself affected by the average age of retirement,

FIGURE 6

TRENDS IN GINI COEFFICIENTS IN CANADA, 1971-97



Source: Statistics Canada, *Income After Tax, Distributions by Size in Canada.*

average years of schooling, and female attitudes toward work outside the home).

Very large declines in hours worked took place in the last third of the 19th century and the first half of the 20th century. For example, standard weekly hours in manufacturing fell from 64.0 in 1870 to 58.6 in 1901, to 50.3 in 1921, and to 43.6 in 1951 (Ostry and Zaidi, 1979, Table IV-1). In the second half of the 20th century, the absolute decline in average hours has been much less.

Figure 4 shows the trends in average hours worked over the 1946-2000 period in Canada for the business sector, manufacturing, and agriculture. For the business sector and agriculture, hours fell around 25 percent from 1946 to the 1980s and have been basically stable thereafter. From 1946 to 1980, the rate of growth in real labour income on an hours-worked basis exceeded that calculated on a worker basis by the decline in the number of hours worked. In manufacturing, the decline has been more modest.

It is important to distinguish between the trends in the average hours worked on a weekly or annual basis by employed persons in a given year and the average amount of time people work over their life cycle or at least to age 65. Offsetting trends are at work in this context. The aggregate female participation rate has more than doubled — from 23 percent in 1950 to 58 percent in 2000 — as more women, particularly married women, have entered the labour force. This has raised the average number of years a woman is working outside the home over her life cycle.

But at the same time, the aggregate male participation rate has fallen from 84 percent in 1950 to 74 percent in 2000. This development largely reflects the falling age of retirement, which has decreased from a median age of 65 as recently as the mid-1980s to 62 by the mid-1990s (Gower, 1997). Another factor is the growing number of years of post-secondary schooling. These trends mean that the average length of time worked by men over their life cycle has fallen in absolute terms, and even more in relative terms when increased life expectancy is factored in.

The relationship between productivity and working time for the employed population is in part mediated by trends in real labour compensation. Higher wages arising from productivity gains may entice workers to substitute leisure or non-working time for additional income if the labour supply curve is backward-bending. In other words, if it takes less time to make the things we need because of productivity gains, people may choose to work less. The large fall in working time during the first seven decades of the 20th century provides evidence of this preference for shorter working time. This development, predicated on the large real wage gains enjoyed during this period arising from higher productivity, represents a major gain in the economic well-being of the workforce not captured by conventional economic statistics.

Since 1970, the downward trend in average hours worked has ended or even been reversed in certain instances, despite continued increase in productivity and real wage growth, although the pace of this growth has certainly been less than in the pre-1970 period. The value of additional leisure from reduced working time below the current levels now appear much less than in the past, at least as evidenced by the decisions of employed persons regarding working time. Institutional constraints and scheduling rigidities may, however, prevent the realization of worker preferences for fewer hours of work. Surveys show that a considerable number of Canadians would prefer to work fewer hours for a prorated cut in wages. But it appears that most full-time workers are satisfied working 35-40 hours per week and do not want a reduction in weekly hours of work, although they may value increased holidays and vacation time. Certainly, productivity gains allow society to choose less working time, although at a cost of less real income. Many European countries appear to be taking this option, which seems much less popular in North America.

The number of years worked over the life cycle is affected by the number of year of post-secondary education and the average age of retirement. Decisions determining investment in education and the age of retirement are affected at least indirectly by the level of productivity or wealth of a society. For example, the decision to retire depends on the generosity of public and private pensions. Increased productivity and a larger tax base allow for the enrichment of the public pension system (including subsidies for RRSPs). With the phasing-in of the Canada Pension Plan and the establishment of the Guaranteed Income Supplement in the 1960s and 1970s, public pensions were significantly expanded, allowing many Canadians to retire earlier than would have been possible without this additional income. The rapid economic and productivity growth of the post-war period up to 1973 was a key precondition for the enrichment of the public pension system. Increases in productivity can lead to better returns on private pension plans through rising stock market valuations based on productivity-enhanced earnings, increasing the incentive to retire.

The decision to pursue post-secondary education may be linked to the rate of return on such investment. Higher aggregate productivity growth raises real labour compensation and can provide a stronger incentive to accumulate human capital, particularly if the returns on occupations requiring higher education exceed those of occupations with lower educational requirements. The average number of years in post-secondary education is also linked to the educational opportunities available to the population. A well-developed post-secondary education sector, as exists in Canada through an extensive system of community colleges, facilitates high post-secondary enrolment rates..Again, the large tax base needed to finance such public investments is predicated on the wealth of the country, in turn a reflection of high productivity levels.

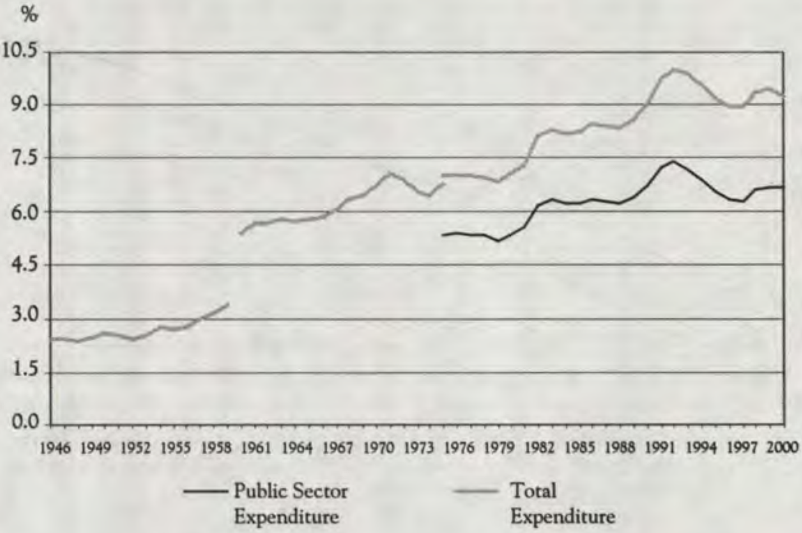
Life Expectancy

A strong case can be made that longer life expectancy increases economic well-being and should be factored into measures of well-being. The Index of Economic Well-being attempts to capture this through an upward adjustment in private consumption proportionate to the percentage increase in life expectancy.

Life expectancy in Canada has steadily increased over the post-war period, up 12.3 years, or 18.5 percent, from 66.6 years in 1946 to 78.9 years in 1999 (Figure 8). There is no significant direct relationship running from productivity and income to longevity in developed countries. Indeed, a large number of developed countries have longer life expectancy than the United States, the richest country. But there are a number of indirect links.[5]

FIGURE 7

HEALTH EXPENDITURE AS A PERCENTAGE OF GDP, 1946-2000



Note: Total health expenditure before 1960 includes only expenditure on hospitals, physicians, dentists, and prescribed drugs.

Source: Health expenditure data for 1946-75 are taken from the *Historical Statistics of Canada*, and for 1975-2000 they come from the Canadian Institute of Health Information. Nominal GDP data are taken from the *National Accounts* for 1961-2000, linked to a series from the *Historical Statistics of Canada* for 1946-61.

In theory, higher income arising from productivity gains allows individuals to purchase better health care, or the government to supply better health care services. In the immediate post-war period, almost all health care expenditures were private. With the introduction of hospital insurance in the late 1950s and medicare in the mid-1960s, public health spending became much larger both in absolute terms and as a proportion of total health expenditure. From 1946 to 1965, a period when most health care expenditure was private, there was a strong upward trend in the share of GDP devoted to health care (Figure 7). Rising real incomes certainly fuelled that increase in health expenditure.

Since 1975, around three-quarters of health care spending has come from the public sector. Public health expenditure has risen from 5.3 percent of GDP in 1973 (the earliest year for which data are available) to a peak of 7.3 percent in 1991, before falling back to 6.4 percent with fiscal retrenchment in the

FIGURE 8

LIFE EXPECTANCY AT BIRTH, 1946-2000

Source: Statistics Canada, *Births and Deaths, 1995*, Cat. No. 84-210. Data are only available for 1946, 1951, 1956, 1961, 1966, 1971, 1976, 1981, 1986, 1991, and 1994-97. Data for all other years are based on linear interpolation and extrapolation.

mid-1990s. Public health spending contributes to higher life expectancy in many ways, including improvement in public health services to reduce infant mortality and funding research that advances medical knowledge.

Regrettables

Certain types of consumer expenditures do not contribute to economic well-being; rather, they are necessary but regrettable expenditures forced on consumers by the exigencies of modern life. A true measure of economic well-being subtracts these expenditures from consumption. The Index of Economic Well-being identifies four of these regrettables — the cost of auto accidents, the cost of pollution abatement equipment, the cost of commuting, and the cost of crime — and subtracts these from private consumption.

The relationships between productivity and these four regrettables are complex and can be both positive and negative. For example, higher productivity and real income can increase the number of auto accidents as there is more economic activity and traffic, but it can reduce accidents through increased public expenditure on safer roads. Higher productivity and real income can also increase the cost of pollution abatement because of higher pollution levels associated with increased economic activity, while at the same time people with higher income may be willing to pay for and accept more regulation of pollution, which reduces pollution abatement costs. The cost of commuting rises with higher levels of economic activity as more traffic lengthens commuting time. The cost of commuting can be reduced when a larger tax base allows public investment in public transit or highways.

The relationship between productivity and the cost of crime is less clear than for the three other types of regrettables. An inequitable distribution of productivity and real income gains, for example with the creation of a small very rich class, may foster crime. More likely, the larger tax base from productivity growth opens the possibility of directing social spending at the social roots of crime.

Public Consumption

Economic well-being can be improved by an increased supply of public goods, and public consumption is included in consumption flows in the Index of Economic Well-being. Higher income arising from productivity gains results in additional tax revenues under almost all types of tax regimes (the exception would be a tax system completely funded by a head or poll tax). Part of these revenues can be used to finance the provision of public goods and services (e.g. education, health services, parks, defence, etc.) without charge, or on a heavily subsidized basis, to the population; this represents public consumption, which is an important part of total consumption. Government expenditures on transfers to persons are not included in public consumption, as the funds are used by recipients to finance private consumption.

Of course, higher productivity increases the tax base and allows for, but does not automatically lead to, increases in public consumption. With more income, governments may choose to lower taxes, or spend the additional revenues in other ways (e.g. pay down the debt, increase transfer payments, make capital spending).

With the rising tax base, government expenditures rose 200 percent on a per capita basis, or at a 2.0 percent average annual rate.

Unpaid Labour

The Index of Economic Well-being considers unpaid labour, both within the household (homework) and outside (volunteer work), as contributing to economic well-being, and it adds the value (estimated on a replacement, generalist basis) of unpaid work to private and public consumption. An increase in the number of hours of unpaid work thus raises economic well-being.

Productivity gains can have indirect effects on the amount of unpaid labour undertaken by society in at least two ways. First, if higher productivity increases real incomes and workers substitute non-working time for working time and reduce the annual number of hours worked, some of this additional non-working time may be used for housework, or more likely, for volunteer work. Second, technological change as represented by the introduction of new household technologies means that a given task requires less hours of effort. This may decrease the amount of unpaid work, assuming other tasks are not found (consumer expenditure may increase as consumer durables are substituted for time).

For example, advances in household technologies — the washing machine, dishwasher, freezer, microwave, etc. — reduce the number of hours of work needed to operate and maintain a household, although the labour-saving benefits of such technological developments may be offset by rising standards for cleanliness and other aspects. An example in the volunteer sector would be the introduction of a machine that licks and stuffs envelopes, a traditional task undertaken by volunteers for political parties. This reduces the need for volunteers, at least for this task (there may be limitless other uses for their time).

On the assumption that additional unpaid work adds to economic well-being measures used in the construction of the Index of Economic Well-being, productivity gains in the household and volunteer sector that reduce the number of hours required for a given set of tasks actually reduce economic well-being. This result seems at odds with common sense as labour-saving innovations should in theory make us better off. There are a number of approaches to resolve this issue. For example, one might assume that the time saved in certain tasks because of productivity-enhancing technologies is used in new, equally useful household and volunteer tasks from a personal or social point of view, so that there would be no change in the number of hours expended (actual trends in unpaid hours will validate or invalidate this assumption). Another approach may be to re-value the time spent on household and volunteer tasks at a higher rate if less hours are expended due to productivity gains, because of the higher opportunity cost of unpaid labour.

Stocks of Wealth

STOCKS OF WEALTH REPRESENT THE SUSTAINABILITY COMPONENT of economic well-being. While the depletion of stocks of wealth such as natural resources may add to current income, it reduces the potential income of future generations, and hence should be factored into measures of economic well-being that take into account intergenerational equity. The components of wealth stocks in the Index of Economic Well-being are physical capital, R&D capital, human capital, natural resources, net foreign debt, and the social costs of environmental degradation. Increases in these components, measured on a constant price, per capita basis, raise economic well-being.

Physical Capital

There is a direct link between productivity and the physical residential and non-residential capital stock. Higher productivity leads to higher national income, which means higher profits. Profits are a key determinant of investment, and additional investment augments the capital stock. Technological change, the key driver of productivity growth, can also have a negative effect on certain components of the capital stock, rendering them economically obsolete. But this effect relative to the aggregate capital stock is normally much smaller than the positive effect of productivity and economic growth on investment and, hence, the capital stock.

Between 1946 and 2000, the per capita stock of real non-residential capital rose at an average annual rate of 2.06 percent (Table 3 and Figure 3). The pace of capital accumulation was, to a significant extent, negatively affected by the post-1973 productivity slowdown. From 1946 to 1973, the very robust productivity growth of 4.03 percent per year was associated with a 3.09 percent rate of increase in the capital stock. The deceleration of productivity growth after 1973, to 1.24 percent, lead to a fall in the rate of capital accumulation of 1.04 percent, one half the pace observed in the pre-1973 period.

Research and Development

The link between productivity and R&D is also direct. Higher productivity increases income and profits. The additional profits serve to finance increased R&D spending, which adds to the stock of R&D.

Human Capital

Higher productivity and incomes can have at least two effects on human capital. First, if people have additional income they may use that to personally accumulate human capital through their own expenditure. Second, and more importantly, higher productivity and incomes lead to larger tax revenues, giving the government more means to support human capital accumulation through investment in the education system.

Natural Resources

One might think that there is no link between productivity and the stock of natural resources, or even a negative link. With higher productivity and incomes, consumption will increase and consequently our stock of natural resources will be run down. That can certainly happen, as the famous 1972 Club of Rome report emphasized.

But the stock of natural resources is linked to the price of natural resources. The greater demand for natural resources arising from higher incomes raises their prices. Higher prices lead to increased supply through greater exploration and development efforts, which increase the proven stocks of natural resources, as well as to reduced demand through the use of substitutes. In addition, productivity gains arising from technological advances in the natural resources sector can actually increase the stocks of resources by lowering production costs and rendering economically viable reserves that were previously uneconomic. For example, technological progress has reduced the cost of extracting oil from the tar sands of Northern Alberta, with the result that the size of the economically viable reserves has increased significantly. Equally, productivity gains in animal husbandry have been impressive in the agricultural sector.[6] So, productivity growth can actually have a positive effect on the overall sustainability of our environment by reducing the cost of extraction and therefore increasing the economic supply of natural resources.

Net Foreign Debt

The link between productivity and net foreign debt is not obvious and one can hypothesize a number of possible relationships. Higher productivity has implications for the balance of payments as it can affect imports, exports and capital flows. A productivity and growth boom can increase imports and raise the foreign debt. It can also create an export spurt, due to increased competitiveness, that will reduce debt. It may also make the country more attractive for foreign investors, and thus increase debt. There are no *a priori* reasons why any of these tendencies should be dominant. The United States is currently enjoying very strong productivity growth and its foreign debt is soaring because of a large trade deficit.

Social Costs of Environmental Degradation

As with its impact on natural resources, productivity growth can have both a positive and negative effect on the environment and on the social costs of environmental degradation. Higher economic growth fuelled by productivity gains can increase the level of pollution as additional economic activity generates more emissions and waste. This is certainly in line with the environmentalist perspective on the issue.

But technological advances associated with productivity growth can also lead to cleaner and more environmentally-sensitive production processes that reduce environmental degradation. Moreover, richer societies give a higher priority to environmental problems than poorer societies, and are more able and willing to pay the price of stiffer pollution controls or to absorb the costs of cleaning up the effects of pollution. Richer countries score much better than poor countries on many environmental indicators.

There is a spirited debate on overall trends in the quality of the environment in Canada and other countries, and there is no consensus on the issue.[7] To be sure, quantification of environmental trends is very difficult.[8] One attempt in this direction has been the environmental indicators produced by the Fraser Institute (Jones, Griggs and Fredericksen, 2000). This study shows that the overall relative severity of environmental problems in Canada has actually declined over time, and that environmental quality had improved 18 percent by 1997 relative to the situation in 1981. According to the Fraser Institute, four of the five general areas of environmental concern experienced declining relative severity, ranging from a 44 percent decline in the severity of environmental problems linked to water quality, to 36 percent for air quality, to 10 percent for land, and to 8 percent for natural resources. The only increase found in the relative severity of environmental problems was in the solid waste area, up 3 percent. Similar trends were observed for the United States and the United Kingdom, but not for Mexico.

These trends support the view that economic and productivity growth is positively associated with improvements in environmental quality through a number of mechanisms, including technological advances that directly reduce pollution and a high income elasticity for environmental quality.

INEQUALITY

THE DEGREE OF EQUALITY IN A SOCIETY is a component of the overall economic well-being of that society, and there is wide agreement that increases in equality (or decreases in inequality) raise economic well-being, at least within the current range of values posted for this variable in OECD countries. The Index of Economic Well-being includes two income distribution variables, a measure of poverty intensity (the product of the poverty rate or incidence and of the poverty gap), which reflects the income distribution of low-income persons, and the Gini coefficient, which measures the equality of income among the overall population.

Poverty Intensity

A key issue in the discussion of the relationship between productivity and poverty is whether an absolute or relative concept of poverty should be employed. If one uses an absolute concept of poverty, then higher incomes through productivity gains can pull individuals above the poverty line. There is a direct link between productivity and poverty, both through the market income people earn and potentially through increased government transfers from the expanded tax base to people who are unable to participate in market activities.

Indeed, Statistics Canada's Low-Income Cutoffs (LICO), which capture trends in absolute poverty, show that the proportion of Canadian households below the poverty line fell significantly in the 1950s, 1960s and early 1970s when economic and productivity growth was robust. But this downward movement in the absolute poverty rate ended, or at best progressed at a much slower rate, after the mid-1970s when the economy entered a period of slower economic and productivity growth. From this perspective, there is a direct relationship running from productivity gains and to reductions in absolute poverty.

With a relative definition of poverty, such as the definition used in the Index of Economic Well-being of households with less than one half of the median equivalent income, there is a lesser direct link between productivity and poverty. If everyone receives the same percentage increase in income as a result of productivity gains, there is no change in the relative distribution of income, and hence in the poverty rate.

One might make the case that if Canadians are richer, there might be more political will to help people at the bottom of the income scale through redistribution policies and relative poverty could then fall. In reality, however, there has been little decrease in relative poverty in the overall Canadian population over the last three decades.[9] The relative poverty rate fell from 13.7 percent in 1973 to 12.5 percent in 1997, while the average poverty gap, that is the shortfall in income for poor families as a proportion of the poverty line, exhibited even less of a decline, from 32.1 percent to 31.8 percent of the poverty threshold between 1973 and 1997 (Osberg and Sharpe, 2002).

Income Distribution

The impact of economic and productivity growth on the overall income distribution of the population is a complex issue. A key consideration is the definition of income used, whether market income, money income (which includes transfer payments) or after-tax income. Market forces largely influence market income, while government policies through transfers and taxes directly affect both money income and after-tax income and reduce inequality.

In certain historical circumstances, productivity and economic growth may lead to a narrowing of market income differentials as persons at the bottom are brought into middle-income jobs. In other situations, growth may be associated with skill-biased technical change and benefit the highly skilled and educated to the detriment of the poorly educated, increasing market inequalities. Since market income inequalities increased in Canada over the last three decades, the second scenario seems more relevant to the Canadian experience.

Higher productivity and real income growth also expands the tax base, giving the government at least the potential to reduce after-tax income inequalities by increasing money transfers to low-income individuals, lowering taxes on the poor and raising them on the non-poor, and implementing social policies that improve the earning potential of the poor.

The Gini coefficient, probably the most widely-used measure of income distribution, shows that market income inequality for all households rose 10.7 percent between 1971 and 1997 (Table 4 and Figure 6). In contrast, the Gini coefficient for income after transfers or money income increased only 0.8 percent while that for after-tax income actually fell 2.7 percent. The tax and transfer system thus acted to offset growing market income inequalities. In 1971, the Gini coefficient for after-tax income inequality was 83.5 percent of that of market income, but by 1997 it had fallen to 73.3 percent. Thus, in 1971, government transfer and tax policies offset 16.5 percent of market income inequality. By 1997, this had increased to 26.7 percent.

ECONOMIC SECURITY

THE DEGREE OF ECONOMIC SECURITY IN SOCIETY is a component of the overall economic well-being and there is wide agreement that an improvement in economic security (or a reduction of economic insecurity) raises economic well-being, at least within the current range of values posted for this variable in OECD countries. The Index of Economic Well-being includes four variables related to economic security, covering four risks faced by the population: the risk of unemployment, the risk of financial distress caused by illness, the risk of single-parent poverty, and the risk of poverty in old age. Higher productivity can reduce all four risks.

Risk of Unemployment

In terms of the financial risk arising from unemployment, many people in the past have believed that productivity gains would lead to higher unemployment, thus reducing economic well-being. But according to public opinion surveys (Graves, 1999), three quarters of Canadians do not think that productivity gains are synonymous with job losses and believe that, in the long run, productivity actually can have a positive effect on unemployment, or at least not have a negative effect on it. Economic theory and analysis support this view. It is now well recognized that it is the aggregate demand and the demographic structure that determine employment and unemployment levels in the long run, not the pace of productivity growth. During the post-war period in Canada, there has been no causal relationship between the unemployment rate and productivity growth and no evidence that productivity gains have lead to long-run technological unemployment.

TABLE 4

GINI COEFFICIENTS FOR CANADA, ALL UNITS

	Market Income	Income After Transfers	Income After Tax	After Tax Income as a Percentage of Market Income
1971	0.447	0.400	0.373	83.45
1972	0.446	0.395	0.368	82.51
1973	0.445	0.392	0.368	82.70
1974	0.441	0.389	0.363	82.31
1975	0.451	0.392	0.364	80.71
1976	0.462	0.402	0.374	80.95
1977	0.445	0.388	0.362	81.35
1978	0.445	0.394	0.367	82.47
1979	0.436	0.381	0.355	81.42
1980	0.442	0.383	0.358	81.00
1981	0.437	0.377	0.351	80.32
1982	0.453	0.381	0.353	77.92
1983	0.471	0.393	0.363	77.07
1984	0.469	0.389	0.359	76.55
1985	0.466	0.388	0.358	76.82
1986	0.467	0.389	0.359	76.87
1987	0.468	0.390	0.357	76.28
1988	0.469	0.390	0.355	75.69
1989	0.461	0.386	0.352	76.36
1990	0.470	0.389	0.352	74.89
1991	0.486	0.395	0.357	73.46
1992	0.491	0.394	0.356	72.51
1993	0.497	0.396	0.358	72.03
1994	0.495	0.394	0.354	71.52
1995	0.493	0.397	0.357	72.41
1996	0.498	0.403	0.362	72.69
1997	0.495	0.403	0.363	73.33

Source: Statistics Canada, *Income After Tax, Distributions by Size in Canada*.

In addition, with higher productivity, incomes and tax revenues, we can choose to have a more generous social welfare system, including better employment insurance coverage and benefits. Higher levels of economic well-being would result from this greater generosity because the financial risks associated with unemployment would be reduced. The Canadian unemployment insurance system was made more generous in the early 1970s after two decades of very rapid productivity growth. It was tightened up in the 1990s after two decades of mediocre productivity growth. While political factors played a role, underlying economic conditions, including productivity growth, largely conditioned these developments. It is much easier to enrich a social program in periods of rapid growth and expanding tax revenues. However, during periods of weak growth and declining revenues, social programs become candidates for retrenchment.

Financial Risk from Illness

As for the financial risks associated with illness, larger productivity gains leading to higher incomes and tax revenues again strengthen the possibility of both private and public expenditure on health, which would reduce the financial risk associated with sickness and improve economic security. The introduction of medicare in Canada in the mid-1960s, a period of rapid productivity growth and rising tax revenues, represented a massive reduction in the financial risk from illness for Canadians. The delisting by provincial governments of certain medical procedures in the mid-1990s, precipitated by the fiscal crisis arising from weak economic and productivity growth, increased the financial risk associated with illness.

Risk of Single-parent Poverty

Productivity gains can reduce the rate of poverty among single parent families through higher real wages and an expanded tax base that allows greater generosity in income transfers and the provision of services to single parents to help them become self-reliant. The weak productivity and income growth during the first half of the 1990s provided little opportunity for single-parent families to pull themselves out of poverty, either through real wage gains or enrichment of social programs. Indeed, the poverty rate for female single-parent families, based on Statistics Canada's after-tax LICOs, actually rose from 48.0 percent in 1989 to 52.3 percent in 1996 (Statistics Canada, 2001). With the strong economic growth in the late 1990s, the poverty rate for families headed by female lone parents dropped, reaching 45.1 percent in 1999. The improved fiscal picture of the late 1990s arising from the economic turnaround allowed the government to introduce the National Child Benefit Supplements in 1998, which contributed to the reduction of the poverty rate in this group (Sharpe, 2002).

Risk of Poverty in Old Age

The implications of productivity growth for poverty among the elderly are largely transmitted through the impact of productivity on the ability of governments to fund transfers to the elderly given the low labour market participation of this group. The strong productivity growth and rising tax revenues experienced up to the mid-1970s allowed governments to greatly increase transfers to seniors through the introduction of the Canada/Quebec Pension Plans and the Guaranteed Income Supplement. This resulted in a major reduction of poverty among seniors. In 1961, the poverty rate for persons 65 and over, based on Statistics Canada's before-tax LICOs, was around 70 percent. By 1973, it had dropped by more than half to 33 percent, and by 1997 to 19 percent (Osberg, 2001). The fight against elderly poverty in Canada has been a success story, fuelled by government commitment and the resources generated by productivity growth.

THE IMPACT OF ECONOMIC WELL-BEING ON PRODUCTIVITY

THE PREVIOUS SECTION OF THE PAPER discussed the linkages running from productivity to economic well-being through the four dimensions or components of the Index of Economic Well-being. In this section, we look more briefly at the relationship running in the other direction, namely, the impact of changes in economic well-being on productivity. In many instances, exogenous improvements in a number of the variables contributing to economic well-being can boost productivity growth.

CONSUMPTION

HIGHER REAL WAGES, increases in certain categories of government spending and declines in work time — all developments that improve economic well-being — can also increase productivity. As noted earlier, the relationship between real wages and productivity can run from wages to productivity as well as from productivity to wages. The price of labour relative to other factors of production determines the relative intensity of labour used in the production process. *Ceteris paribus*, the higher the wages, the less labour employed, and the higher the average productivity of the labour actually used, as more capital-intensive methods of production are adopted. Thus, exogenous wage shocks can lead to factor adjustments that raise labour productivity to higher levels.

Government spending in a number of areas, including infrastructure, R&D spending, and education and training, can boost private sector productivity. Decreases in the length of the average work week can increase productivity, measured on an hours-of-work basis, because workers work more intensely during the shorter work period. This finding has often been observed in cases where a shorter work week was introduced.

STOCKS OF WEALTH

STOCKS OF WEALTH ARE INPUTS into the economy's aggregate production function. Thus, exogenous increases in the capital stock, in the R&D stock, and in human capital — all variables in the sustainability component of economic well-being — can boost productivity. Investment, innovation and human capital are the key determinants of productivity growth. The degradation of environmental stocks, such as soil depletion or global warming due to CO_2 emissions can have negative effects on productivity.

There are feedback mechanisms between productivity and wealth stocks. Virtuous circles or spirals are created when higher productivity leads to increased investment and stocks of wealth, which in turn increase productivity, which in turn raises income and investment.

EQUALITY

THE OVERALL IMPACT OF INEQUALITY on economic growth and productivity is complex and still poorly understood, as the paper by Richard Harris in this section of the book makes clear. Traditionally, it was argued that inequality is good for economic growth due to the presence of positive incentive effects. Recently, a literature has developed stressing the negative political economy effects of inequality and the negative impact on human capital accumulation resulting from the liquidity constraints on borrowing by the poor to finance education. More research is needed on this issue before definitive conclusions can be reached.

ECONOMIC SECURITY

AS WAS THE CASE FOR THE IMPACT OF INEQUALITY on economic and productivity growth, the impact of economic security is also poorly understood. Increased economic security contributes to productivity growth through the same mechanisms outlined above for greater equality and less poverty. Indeed, poverty is a key element in two of the four subcomponents of the economic security component in the Index of Economic Well-being. If people feel more secure, both in terms of income and employment, they may be willing to make more investments in human capital. Again, it should be noted that there are positive feedback mechanisms running from productivity to economic security, and from economic security back to productivity. Again, more research is needed on this issue before definitive conclusions can be drawn.

CONCLUSION

TO CONCLUDE, PRODUCTIVITY IS AN IMPORTANT ISSUE for all Canadians. The productivity issue spans the political spectrum. People on the left recognize its importance, as do people in the middle of the political spectrum and those on the right. Even though the interests of certain groups diverge in many areas, the interests of all Canadians come together on this issue. This is because all recognize that productivity growth is essential for real income growth, that is increasing the economic pie, and that income growth can contribute in various manners to improvements in economic well-being. Higher productivity allows society to determine, through both the market and the political arena, whether our greater economic well-being will manifest itself through higher private consumption, more public goods, additional leisure, or greater public transfers to increase equality and economic security.

Indeed, with the expected decline in labour force growth due to falling labour force participation rates associated with the retirement of the baby-boom generation in coming decades, productivity growth will represent an even greater share of economic growth and, hence, an even more important determinant of economic well-being.

Despite the key role of productivity in real income growth, it is important to retain a sense of perspective on the productivity issue. Just because productivity can contribute to higher levels of economic well-being, it does not follow that it should be the top social priority. There is more to life than productivity and even than economic well-being.

Two points are relevant in this regard. First, in poor countries, productivity growth is absolutely crucial in order to raise the material standard of living to an acceptable level and to reduce absolute poverty. In contrast, Canada is already a rich country with high living standards for the vast majority of its population. Increased productivity leads to higher consumption levels and greater economic well-being, but it may do little for subjective well-being, also known as happiness. After a certain income level has been achieved, studies show that there is little if any additional impact on happiness from further real income growth (Easterlin, 1987). Money cannot buy happiness. Since the goal of public policy is to increase the happiness of the population, not just its economic well-being, productivity should not be oversold as a panacea for society's ills (Heath, 2002).

Second, productivity can provide the basis for potential increases in a number of components of economic well-being, such as equality and economic security. But there is no automatic mechanism through which higher productivity growth translates into less income inequality or lower poverty, as is the case with private consumption. For example, growing wage inequality may prevent poorly skilled workers from participating in the benefits of productivity growth. Government action may be needed to eradicate poverty and reduce social inequality.

The objective of this paper has been to highlight the positive two-way linkages between productivity and economic well-being, as defined by the Index of Economic Well-being developed by the Centre for the Study of Living Standards. This has been a relatively straightforward task. What is much more difficult is to show what processes and policies determine productivity growth. That is a much greater challenge. What policy levers do we need to employ to go from a 1 percent productivity world to a 2 percent productivity world? If we could do that, then we would see not just an increase in income, but also improvements in other facets of our economic well-being.

ENDNOTES

1 In the fall of 1998, the Centre for the Study of Living Standards (CSLS) introduced a new indicator of sustainable development for Canada (Osberg and Sharpe, 1998), appropriately called the Index of Economic Well-being (IEWB). Since then, the CSLS has continued to develop the Index, producing estimates for the United States (Osberg and Sharpe, 1999), the Canadian provinces (Osberg and Sharpe, 2000b), OECD countries (Osberg and Sharpe, 2000a, 2001b and forthcoming), and updated estimates for Canada (Osberg and Sharpe, 2001a) and the United States (Osberg and Sharpe, 2001c and 2002). The Index has stimulated much interest among researchers and policy analysts, particularly at the international level.

2 Weights are also applied to the sub-components of the equality and economic security components because these sub-components are not expressed in constant prices and therefore cannot be aggregated. The weights given the poverty intensity and income inequality are, like the weights given to the four components, subjective as they reflect the relative valuation placed on these sub-components. In contrast, the weights given to the four sub-components of economic security have a more objective basis as they reflect the relative importance of the group at risk in the total population.

3 This is especially so when the labour income share is adjusted for changes in unincorporated business income, which includes a labour component.

4 The difference was due to faster growth in the CPI reflecting increased indirect taxes and the falling price of investment goods (primarily information technology) relative to the GDP deflator.

5 In underdeveloped countries, there may be a more direct link between productivity, income and life expectancy, as higher productivity and income lead to better nutrition and health care.

6 For example, the average North American chicken produced 84 eggs per year in 1910. Through selective breeding practices and improved feed, this level has increased to 100 in 1932, 200 in the 1960s, 247 in 1983 and 292 in 1999. The live weight of a broiler chicken more than doubled, from 2 pounds in 1920 to 5.1 pounds in 2000. In the United States, the average yearly milk output of a Brown Swiss milking cow has more than tripled, from 2,300 litres in 1940 to 7,236 litres in 1996 (Strauss, 2002).

7 See, for example, *The Skeptical Environmentalist* (Lomberg, 2001) and the intense debate generated by this recent publication.

8 Problems include the weighting given various environmental indicators, the lack of national time-series data for many indicators, the uncertainty surrounding the effects of environmental trends, and the ignorance of threshold effects whereby permanent damage is done once a certain level is reached. Another issue is the importance given to the precautionary principle.

9 The Survey of Consumer Finances from which poverty rates are calculated is only publicly available since the early 1970s.

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PRODUCTIVITY ISSUES IN CANADA

Productivity growth is the fundamental driver of improvements in real incomes and living standards over the long term. Productivity gains increase the economic pie, freeing additional resources that can be invested to meet the needs of the population in areas such as health care, education, the environment, public infrastructures and social security.

After the first oil price shock in 1973, productivity growth declined sharply in Canada, as in all other OECD countries. Then, in the 1990s, Canada's productivity growth lagged significantly behind that of its largest trading partner, the United States. These worrisome trends generated a great deal of research interest and a lively public debate in Canada.

This collection of research papers on productivity will help better understand the reasons for Canada's relatively weak productivity record and the nature of productivity growth in Canada. They cover a wide range of topics – productivity trends and determinants; innovation and productivity; investment and productivity; global linkages and productivity; productivity in the *new economy*; and the social aspects of productivity. Some papers have already been published by Industry Canada, several figuring prominently in the productivity debate, but many are published here for the first time.

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