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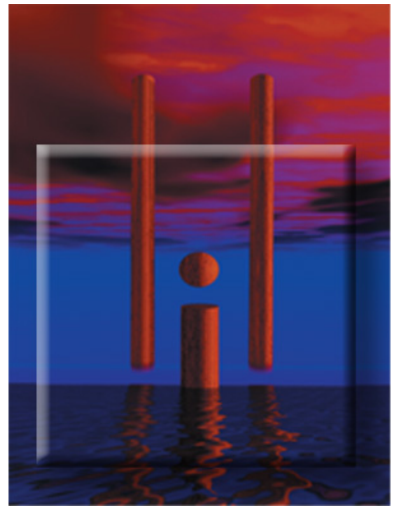

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John R. Baldwin, Desmond Beckstead, Naginder Dhaliwal,
René Durand, Valérie Gaudreault, Tarek M. Harchaoui, Judy Hosein,
Mustapha Kaci, Jean-Pierre Maynard

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Preface

Statistics Canada's productivity program was initiated in the late 1940s. It was the result of recommendations from an interdepartmental committee on productivity analysis, who reviewed the conceptual and measurement problems involved and the available data sources in Canada.

The productivity measures were built on the Canadian System of National Accounts. The productivity program introduced statistical series of output per person employed (i.e., labour productivity) for the commercial (non-agricultural) sector, and its manufacturing and non-manufacturing components.

Initially, labour productivity estimates were the only product. They were of particular interest in labour negotiations between workers and management, where wage-rate increases were sometimes based on average labour productivity gains. They were also of interest to those studying how growth in labour productivity played a vital role in improving real living standards.

By the mid-1970s productivity growth trends had slowed dramatically. A flurry of research studies aimed at explaining the slowdown focused on issues and concepts that went beyond labour productivity. Statistics Canada recognized the desirability of extending its labour productivity program to encompass additional inputs and other innovations coming from recent developments in production theory. Following a feasibility study in the early 1980s, the multifactor productivity program was launched in 1987 as a regular statistical program.

As a result of these major developments, Statistics Canada has published annual indices of multifactor productivity, labour productivity and related measures for broad economic sectors and for more than 100 two- and three-digit 1980 Standard Industrial Classification (1980 SIC-E) business sector establishments (1961 to the present).

This publication adds to our knowledge of productivity measures in Canada by

- providing information on productivity performance in Canada at various levels of industry detail;
- demonstrating how productivity measures are constructed, what their underlying assumptions are, and to what extent estimates may be subject to measurement errors; and
- showing how productivity measures can be used for analytical purposes.

Stewart Wells
Assistant Chief Statistician
National Accounts and Analytical Studies

Introduction

Productivity Growth in Canada is designed to provide a comprehensive guide to analysts, researchers, students and consultants who wish to carry out research with and to interpret productivity measures in Canada.

The publication includes an overview of the standard productivity growth measures, data construction procedures and measurement issues. It considers in detail a number of underlying theoretical concepts and measurement issues. It goes further, however, by illustrating how productivity measures and related economic performance indicators can be used and interpreted.

In addition, a number of empirical studies are included that extend our understanding of uses to which productivity measures can be put. More specifically, in the empirical work, emphasis is placed on the use of microdata and country of control characteristics to examine productivity changes at the firm level. Furthermore, attempts are made to consider the importance of economies of scale, fixity and market power when measuring productivity growth. The publication also devotes special attention to the issue of capital formation, identified by many researchers as an important determinant of economic growth.

The chapters are organized as follows:

a) The first chapter provides an overview of the concepts of both labour and multifactor productivity growth. It also summarizes the trends in productivity performance over the last four decades. The relationship between labour productivity and economic well-being is also discussed.

b) The second chapter considers how productivity growth affects the economy. Two main issues are addressed. The first is the extent to which Canada has been shifting production away from sectors with low productivity to those with higher productivity. The second asks whether and how productivity growth influences structural change. The chapter finds that productivity gains are primarily passed on to consumers via changes in prices, rather than to workers in terms of relative wage changes.

c) The third chapter discusses the types of confidence intervals that should be employed by users of productivity estimates. The chapter highlights the need for statistical indicators that will provide a measure of the reliability of productivity measures to data users. In doing so, it identifies several ways of assessing the boundaries that should be placed around the point estimates of productivity growth—ranging from classical estimation techniques to comparisons of productivity growth rates based on alternate estimation techniques for capital stock. It also discusses problems in international comparisons that use employment rather than hours-worked as a measure of labour input. Based on the differences in the results of these different techniques, it notes that conclusions about changes in productivity trends and differences across countries need to be made cautiously.

d) The fourth chapter discusses differences in productivity growth between Canada and the United States. The chapter examines differences in methodological techniques used in the two countries and then compares the estimates that are produced by Statistics Canada and by the Bureau of Labor Statistics. It finds a close relationship between the two economies for the overall business sector but differences for the manufacturing sector. In the latter area, the largest differences are in computers and electronics. It also examines the effect of making changes to the estimation techniques of both countries that reduce the differences in the methodologies used.

e) The fifth chapter focuses on micro-data and examines labour productivity differences between domestic and foreign-owned firms in the manufacturing sector. This chapter uses micro-data on individual establishment performance to study differences in the growth of labour productivity between domestic and foreign-controlled establishments in the manufacturing sector for the period 1973 to 1993. In doing so, it also examines the extent to which differences exist between small and large establishments and across industry sectors and how they have been changing over time. Foreign-controlled establishments are shown to have higher labour productivity and the highest growth rates over time in labour productivity. In addition, labour productivity has been growing more quickly in large plants than small plants.

f) The sixth chapter focuses on the history of investment and the extent to which the mix between machinery as opposed to buildings and structures has changed over the last twenty years. Since the mid-1980s, the national savings rate has averaged just over 18% of GDP, compared with 24% during the 1960s. One explanation for slower productivity growth since 1975 is that this lower savings rate has constrained investment and thereby deprived the nation of both the tools and the technologies it needs. The chapter shows that the types of private domestic investment in machinery and equipment that determine productivity have fallen less than one might infer from the decline in overall savings. The chapter also notes that capital stock per unit of labour is rising in Canada, but not as fast as in the past. The slower growth of the capital-to-labour ratio is not the result of a restructuring from goods to services.

g) The seventh chapter examines the cyclical behaviour of the labour productivity series. It asks whether the slowdown in growth during the post-1973 period is accompanied by increasing volatility. This chapter uses simple summary statistics to analyse the volatility, persistence, and co-movement of 37 industrial labour productivity series for the period 1961-1996. It seeks to identify the size, source, and correlation of fluctuations in the productivity performance of specific industries within various sample periods and to analyze possible changes in these characteristics over time. It finds that productivity growth in the post-1973 period has become more volatile, that changes have become more persistent, and that the importance of common factors behind these changes has also increased.

h) The eighth chapter provides alternate, experimental estimates of productivity growth that are based on a different methodology than the non-parametric technique that is normally used. It uses parametric multivariate analysis to estimate multifactor productivity growth rates that allow for scale economies and capital fixities. The principal findings are that the normal assumptions used to estimate productivity—that markups are non-zero, that excess capacity generally exists, and that there are constant returns to scale—are incorrect, but that relaxing these assumptions has a relatively small effect on the productivity estimates. It finds that the assumption of constant returns to scale and full capacity tends to decrease the estimate of productivity change by roughly 30% over the period 1961 to 1995, but that the estimate of this 'bias' is not very precise.

i) Appendices 1 to 5 provide productivity estimates, their underlying sources, concepts and methods, and their availability on Cansim.

1 Productivity: Concepts and Trends

John R. Baldwin, Tarek Harchaoui, Judy Hosein and Jean-Pierre Maynard

1.1 Introduction

Productivity is one of several key indicators of the health of an economy. It provides an indication of the productive capability of the economy by measuring how much output an economy produces for a specific amount of resources that it devotes to production.

In the past few years, the productivity of Canadian industries has been the focus of sustained attention. There has been a major slowdown in productivity growth since the prosperous 1960s. Many analysts have tried to explain the causes of this slowdown and its effects on Canada's economy, using measures of both labour and multifactor productivity. This chapter compares the two measures and their trends in recent years. It also examines the relationship between productivity and economic well-being.

1.2 Definition and measurement

Productivity is a measure of the productive capability or efficiency of an economy. It can be defined in terms of a level—how much output is produced per unit of input (e.g., output per worker)—or in terms of a growth rate—the increase in output per worker. Statistics Canada focuses on the growth rate in productivity because of its usefulness in understanding the extent to which improvements in productivity contribute to economic growth.

Economic growth arises from an increase in the quantity of goods and services produced by a country in a given period. The two main sources of economic growth in output are increases in the factors of production (the labour and capital devoted to production) and efficiency or productivity gains that enable an economy to produce more for the same amount of inputs. Increases in productivity may come from many sources: technological progress, economies of scale (firms get larger and more efficient), research and development, and increases in the quality of the inputs that go into the production process. These changes occur on the shop floor.

Measurement of efficiency gains due to productivity growth are derived by subtracting the contribution of the additional quantities of inputs used between two periods from the change in quantity produced. The result, a measure of productivity growth, is the residual portion of growth that cannot be accounted for by the additional quantities of inputs that have been used to produce the increase in outputs observed.

Productivity growth, then, captures the economy's progress in improving its capability of producing output as more inputs are devoted to production. Being able to get more from less tells us, *mutatis mutandis*, about the rate of technological change. In the long term, this productivity measure, because of the way it is calculated, represents the improvement in the efficiency with which a business, industry, or country produces goods and services. In this sense, increased productivity is a key element in improving our economic well-being because, without it, the rate of increase in output would be the same as the increase in the factors of production used.

Two measures of productivity growth

Productivity growth can be measured as the increase in output relative to the increase in a single input like labour (growth in labour productivity) or the increase in output relative to the increase in a bundle of inputs like labour and capital (growth in multifactor productivity).

Labour productivity growth is the most widely used measure. This productivity measure captures the increase in the quantity of goods and services produced per unit of labour (hours worked).[1] It measures the increase in the

[1] Its counterpart is capital productivity—the ratio of output to capital. This measure receives less attention than does labour productivity.

productive capacity of the economy relative to employment. Labour productivity growth is intuitively meaningful since it measures the growth in how much workers are able to produce. It is also of empirical interest since gains in real wage rates closely track gains in labour productivity, as will be shown in Chapter 2.

Output per hour worked or labour productivity is affected by the amount of capital—machinery, equipment and buildings—that is provided to workers. Plants that have more capital tend to have a higher output per hour worked. It is useful to know why labour productivity increases—whether it is because capital per worker increases or because technological changes occur that are unrelated to changes in capital intensity. Towards this end, Statistics Canada also produces a multifactor productivity measure.

Analogous to the concept of labour productivity, multifactor productivity measures the amount of output produced by a standard input bundle that is made up of labour and capital. The *growth* in multifactor productivity refers to the *change* in output relative to the *change* in a bundle of inputs—labour and capital.[2] Since it measures the residual growth not due to both labour and capital growth, it is more comprehensive than just the labour productivity measure—but it may be less accurate because of the complexity of measuring the capital stock.[3]

In summary, a labour productivity growth measure tracks changes in output per hour worked, whereas a multifactor productivity growth measure captures the increase from the growth in production minus the increase of inputs that are devoted to the production process. For example, if output increases by 6% annually and inputs increase by 5%, multifactor productivity increases by 1%.

It should be noted that the two productivity measures are related algebraically.[4] Multifactor productivity growth can be expressed as a weighted average of labour and capital productivity growth:

Multifactor productivity = α*(labour productivity) + β* (capital productivity) (1)

where α and β are the share of GDP in current dollars that goes to labour and capital, respectively.

This formula can be rewritten to express labour productivity growth as a function of the growth in multifactor productivity and the capital-to-labour ratio:

Labour productivity = multifactor productivity + β * (growth in capital/hour) (2)

Labour productivity growth, then, is equal to multifactor productivity growth plus the growth in capital/labour intensity multiplied by capital's share of output. Labour productivity growth will exceed multifactor productivity growth when the capital-to-labour ratio is increasing.

This brief summary has focused on what productivity measures capture. It is also important to stress what they do not measure, since productivity growth is sometimes confused with other important economic measures.

Productivity growth does not necessarily mean that profits and wages have increased. For example, a firm may increase the efficiency of its production process, but if the price for its product falls, it will see profits decline and may be forced to pay its workers less to remain in business. The same can happen for a nation. Productivity can go up, but less can be left for workers' wages if prices have fallen. Canada can produce raw materials more efficiently than anyone else in the world, but if prices of raw materials are falling relative to other products, profits and wages may stagnate despite robust productivity growth. Of course, the reverse can also occur.

Further, productivity growth is not necessarily synonymous with growth in general. High output growth may be associated with low or high productivity growth.

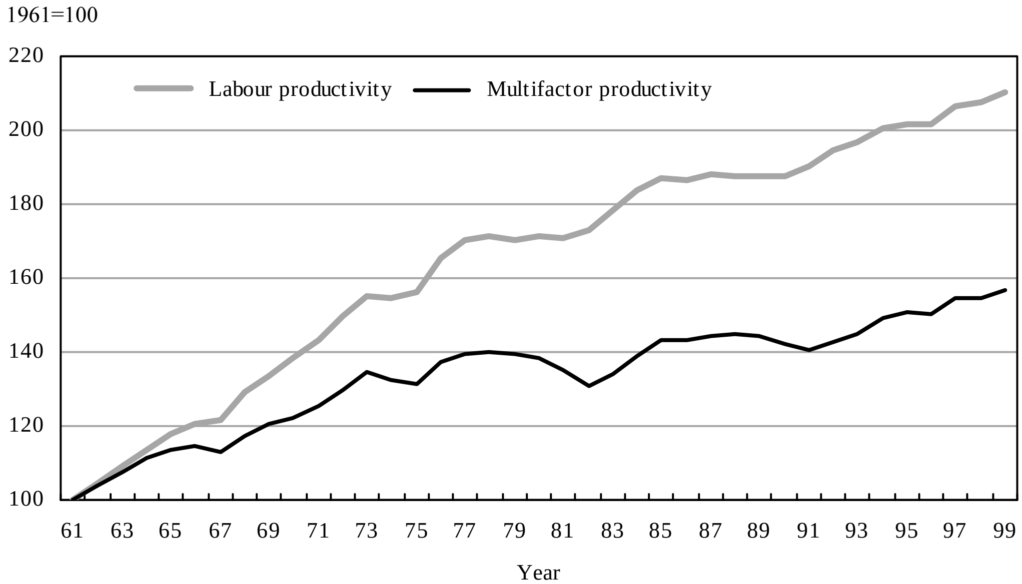
Productivity growth, then, is just one measure that needs to be used in conjunction with others in order to evaluate the state of an economy.

1.3 Trends in labour productivity growth and multifactor productivity growth

Labour productivity in the business sector[5] has generally experienced a higher rate of growth than multifactor productivity (Figure 1.1). Since 1961, labour productivity has

[2] This definition applies when output is defined as value added. When output is defined as gross output the bundle of inputs includes labour, capital and materials. See Appendix 1 for a discussion of these various concepts.
[3] See Chapter 3 for a discussion of measurement problems associated with productivity estimates.
[4] For a discussion of the relationship between multifactor and labour productivity measures, see Appendix 1.
[5] Statistics Canada's productivity indices cover the business sector—the economy less those sectors that are primarily non-profit. For further definitions, see Appendix 1.

Figure 1.1 Cumulative multifactor productivity growth[1] and labour productivity growth for the business sector, 1961-1999



Note: 1. Based on value-added measure.

grown at an average annualized rate of 2.0%. This compares with an average annualized rate of 1.2% for multifactor productivity. The difference between these two is explained by an increase in the capital-to-labour ratio over the period 1961-1999. Since the early 1960s, Canadian businesses have become far more automated. This has meant a steady increase in the quantity of capital per worker. Faster growth in labour productivity surpassed growth in multifactor productivity in large measure because the amount of capital per worker has been increasing.

Short-run productivity estimates

Annual estimates of productivity growth are highly variable over time (Figure 1.2). This occurs because inputs are not adjusted to changes in output quickly. Increases in demand may be unanticipated, and firms may not be able to increase their factor inputs as rapidly as desired. Similarly, decreases in output may not be accompanied by rapid adjustments in factor inputs.

Reducing capital inputs during a recession occurs slowly. Businesses rarely discard capital stock during an economic slowdown; rather, they tend to decrease the intensity of its use. Also, since investment decisions are made well in advance, capital stock usually continues to increase in the early part of a recession, when production starts to decline. Labour inputs also have some of the characteristics of fixed inputs. Where special skills have been imparted to the work force by on-the-job training, firms are reluctant to lose employees by laying them off. Despite this, adaptation of employment to changing demand is generally regarded as occurring more readily than the adaptation of capital stock. In a recession, firms do discharge workers, although not proportionately to the decline in output. Similarly, in a recession, some capital may be discharged, but most is kept in abeyance until demand turns around and begins to grow again.[6]

As a result, there are large fluctuations in the annual or short-run productivity estimates, especially during downturns of the business cycle. The labour productivity estimates have about the same variance as the multifactor productivity estimates—with standard deviations of 1.9 and 2.0 percentage points, respectively. However, the coefficient of variation (the ratio of the standard deviation to the mean) is lower for labour productivity than for multifactor productivity—at 0.9 and 1.6, respectively.

The volatility in these estimates means that changes in longer-run trends are difficult to detect in the short run. An evaluation of the performance of productivity is best done using data over longer periods, such as from peak to peak of an economic cycle. For instance, the calculation

[6] Variations in capital utilization are taken into account when estimating multifactor productivity by calculating the capital share on an annual basis. In a recession, this share declines.

Figure 1.2 Volatility of productivity series, annual growth rates, 1962-1999

Note: 1. Based on value-added.

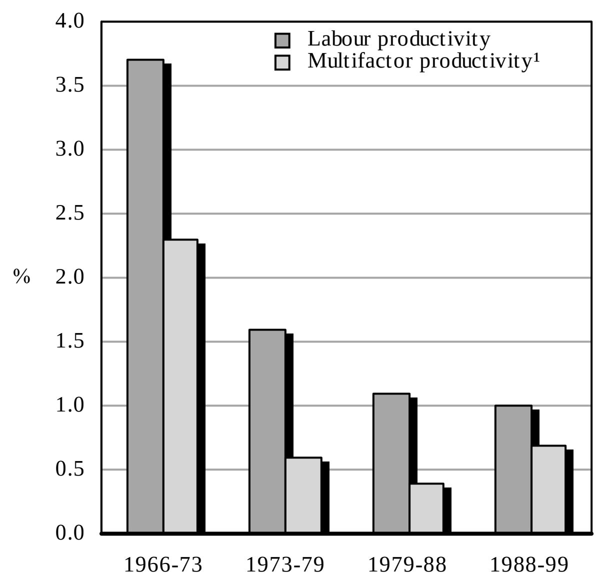
of the productivity performance is understated in the 1990s, if 1988 is used as a starting point and the early years of the 1990s are used as an end point (peak to trough). In the same vein, reading too much into any particular year's productivity estimate is risky because high levels of growth in one period are often followed by low growth in the next. It is the long-term growth of productivity over a cycle that is most meaningful in terms of understanding growth trends.

Long-term trends

Since 1961, the Canadian economy has gone through four cycles of productivity growth: from 1966 to 1973; from 1973 to 1979; from 1979 to 1988; and from 1988 to 1999. Long-term trends in both the multifactor and the labour productivity index confirm that the productivity growth rate has been slower in recent years than in the period prior to 1973. Figure 1.3 shows the average multifactor and labour productivity growth rates for these four economic cycles.[7] Prior to 1973, labour productivity grew by 3.7%. In the post-1973 period, labour productivity experienced lower rates of growth in all subsequent cycles ranging from 1.6% in the 1973-1979 cycle to 1.0% in the 1988-1999 cycle. Similarly, multifactor productivity growth was 2.3% prior to 1973 but only 0.6%, 0.4%, and 0.7% in the subsequent three cycles. Multifactor productivity growth rates have been more or less steady for the last three cycles, though much lower than in the period prior to 1973.

[7] The last cycle in the 1990s is not complete.

Figure 1.3 Multifactor productivity and labour productivity, average growth rates, selected periods



Note: 1. Based on value-added.

1.4 Sources of growth

As was explained in Section 1.2, the multifactor productivity index based on GDP is produced from an accounting exercise that decomposes the sources of output growth into three components: productivity growth, capital growth and labour growth. In Table 1.1, the rate of growth in output is divided into growth from increased labour inputs,

Table 1.1 Annualized rates of growth of output[1] and contributions by type of input, selected periods

	1961-99	1961-66	1966-73	1973-79	1979-88	1988-99
			%			
Business Sector						
Output	3.8	6.9	4.9	3.5	3.1	2.5
Contribution of Capital	1.4	1.5	1.6	1.6	1.5	1.0
Contribution of Labour	1.2	2.4	1.0	1.3	1.2	0.8
Multifactor Productivity	1.2	2.9	2.3	0.6	0.4	0.7
Services						
Output	4.3	6.2	5.6	4.7	3.7	3.0
Contribution of Capital	1.5	1.6	1.5	1.6	1.6	1.4
Contribution of Labour	1.9	2.7	1.8	2.3	2.0	1.4
Multifactor Productivity	0.9	1.9	2.3	0.8	0.2	0.2
Goods						
Output	3.2	7.4	4.2	2.4	2.5	1.8
Contribution of Capital	1.3	1.5	1.7	1.6	1.4	0.5
Contribution of Labour	0.5	2.2	0.3	0.3	0.4	0.1
Multifactor Productivity	1.5	3.7	2.3	0.5	0.6	1.2
Manufacturing						
Output	3.7	8.9	4.9	2.5	2.5	2.3
Contribution of Capital	0.9	1.3	1.4	0.6	0.9	0.7
Contribution of Labour	0.6	2.9	0.7	0.2	0.2	0.0
Multifactor Productivity	2.2	4.6	2.7	1.7	1.4	1.6

Note: 1. Based on value-added.

increased capital inputs, and residual growth from productivity improvements. The contribution made by labour and capital is just the rate of growth of each of these inputs weighted by their respective income shares. For example, over the period 1961 to 1999, business sector output grew by 3.8% annually. Of this, 1.2% came from labour growth, 1.4% from capital growth, and the residual (1.2%) was productivity growth.

The annual growth of output has varied considerably over the period. At 6.9% per year, it was highest in the first period, 1961-1966, but it steadily declined to 2.5% in the 1988-1999 period. Throughout the first four periods, capital growth made about the same contribution to total growth—1.5% to 1.6%. Labour's contribution was highest in the first and fastest-growing period at 2.4%. It dropped to about 1% in the 1970s and 1980s. Since 1966, labour growth has contributed less to overall growth than has capital growth.

Multifactor productivity growth was much more important in the first two periods—at 2.9% and 2.3%, respectively. However, its contribution to output growth in the last three periods was lower than before 1973. Labour productivity growth in the last three periods was also significantly lower than in the period prior to 1973.

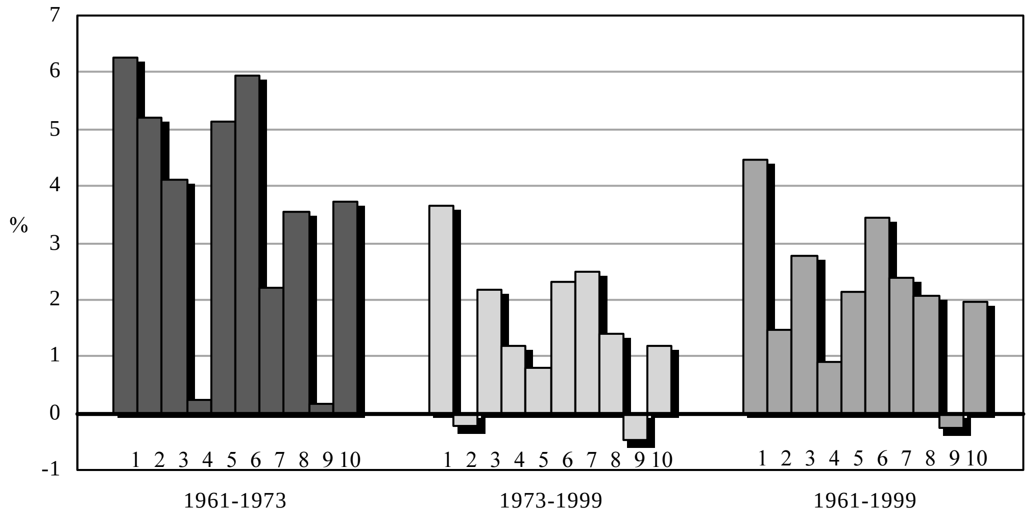
It is important to note that the economy exhibited slower overall growth during the 1990s as compared with the 1970s and 1980s. This was not because multifactor productivity growth declined rapidly, but because growth in employment and capital declined at a faster rate than growth in multifactor productivity *per se*. Over the historical period 1961 to 1999, the contribution of multifactor productivity to the growth of output in the business sector was equal to that of labour and capital (approximately 32%). However, productivity played a larger role in the growth of the output of the Canadian business sector during the period 1966-1973, when it accounted for 47% of output growth. This contribution fell to about 15% in the 1970s and 1980s, and increased in the latest period (1988-1999) to 28%.

The main source of output growth varies by sector. In the services-producing sectors, labour was the engine of output growth, with a contribution of close to 50% in the post-1973 periods. By contrast, in the goods-producing sector, capital was the most important source of growth, contributing over 50% during the 1973-1979 and 1979-1988 periods.

1.5 Industry performance

The level of productivity growth for the business sector as a whole depends on the rates of growth in the underlying sectors that make up the economy. The rate of technological change is not the same in all sectors. New technologies and changes in organizational structures that increase productivity are more amenable to application in some industries than others.

Figure 1.4 Labour productivity by industry group, annualized growth rates, selected periods



1- Agricultural and Related Services Industries
2- Other Primary Industries
3- Manufacturing Industries
4- Construction Industries
5- Transportation and Storage Industries
6- Communication and Other Utility Industries
7- Wholesale Trade Industries
8- Retail Trade Industries
9- All Other Services
10- Business Sector

To illustrate these differences, the growth in labour productivity by industry is depicted in Figure 1.4 for the periods before and after 1973. Agriculture, manufacturing, and communications were among the leaders in both periods and, as a consequence, were also among the leaders over the entire time period. In contrast, other primary industries experienced very rapid growth only in the first period, and wholesale trade industries experienced relatively rapid growth only in the second period.

A similar pattern emerges when multifactor productivity is tabulated by industry (Figure 1.5) Once again, agriculture, manufacturing, and communications are among the leaders.

Much has been made of the impact of productivity increases in agriculture. Over this century, these increases have allowed an urban society to develop. The large increases in agricultural productivity in the early 1900s meant that a large urban work force could be supported by a smaller and smaller farm population. The large productivity increases of the agriculture sector in the pre-World War II period have continued into the present. Since the 1960s, the agriculture sector has been one of the leaders in terms of productivity gains.

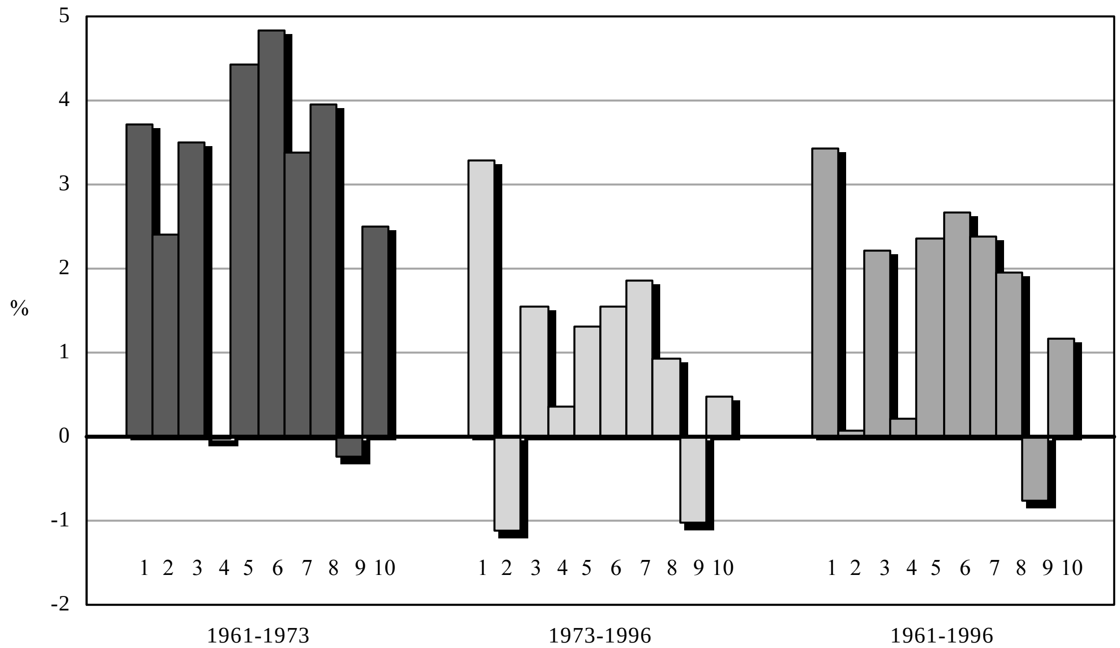
Transportation systems have also produced high productivity gains. New generations of jet aircraft have led to increases in productivity in the airline industry, whereas transportation deregulation and new diesel systems have influenced productivity in the rail industry.

At the same time, the communications industries have experienced dramatic growth in productivity. As new technologies have been introduced, the cost of telephone messages has fallen. Productivity growth in this industry has been just as high as that in the transportation sector.

The two distribution systems (retail and wholesale) have also had relatively high rates of productivity growth. These gains occurred as inventory distribution systems were made more efficient, and as larger stores were constructed.

Despite these gains in the service sectors, strong productivity performance in manufacturing has continued. In this sector, new computer-based technologies in design and engineering, fabrication and assembly, communications, and integrated control processes have improved productivity performance.

Figure 1.5 Multifactor productivity[1] by industry group, annualized growth rates, selected periods



1- Agricultural and Related Services Industries
2- Other Primary Industries
3- Manufacturing Industries
4- Construction Industries
5- Transportation and Storage Industries
6- Communication and Other Utility Industries
7- Wholesale Trade Industries
8- Retail Trade Industries
9- All Other Services
10- Business Sector

Note: 1. Based on value-added.

The relative contribution of productivity growth in selected industries to overall aggregate productivity growth is presented in Figure 1.6 for the period 1961 to 1995 along with the relative importance of each sector as measured by its share of value added. The contribution to aggregate productivity growth is measured by weighting the productivity growth of each industry grouping by its nominal share of output.

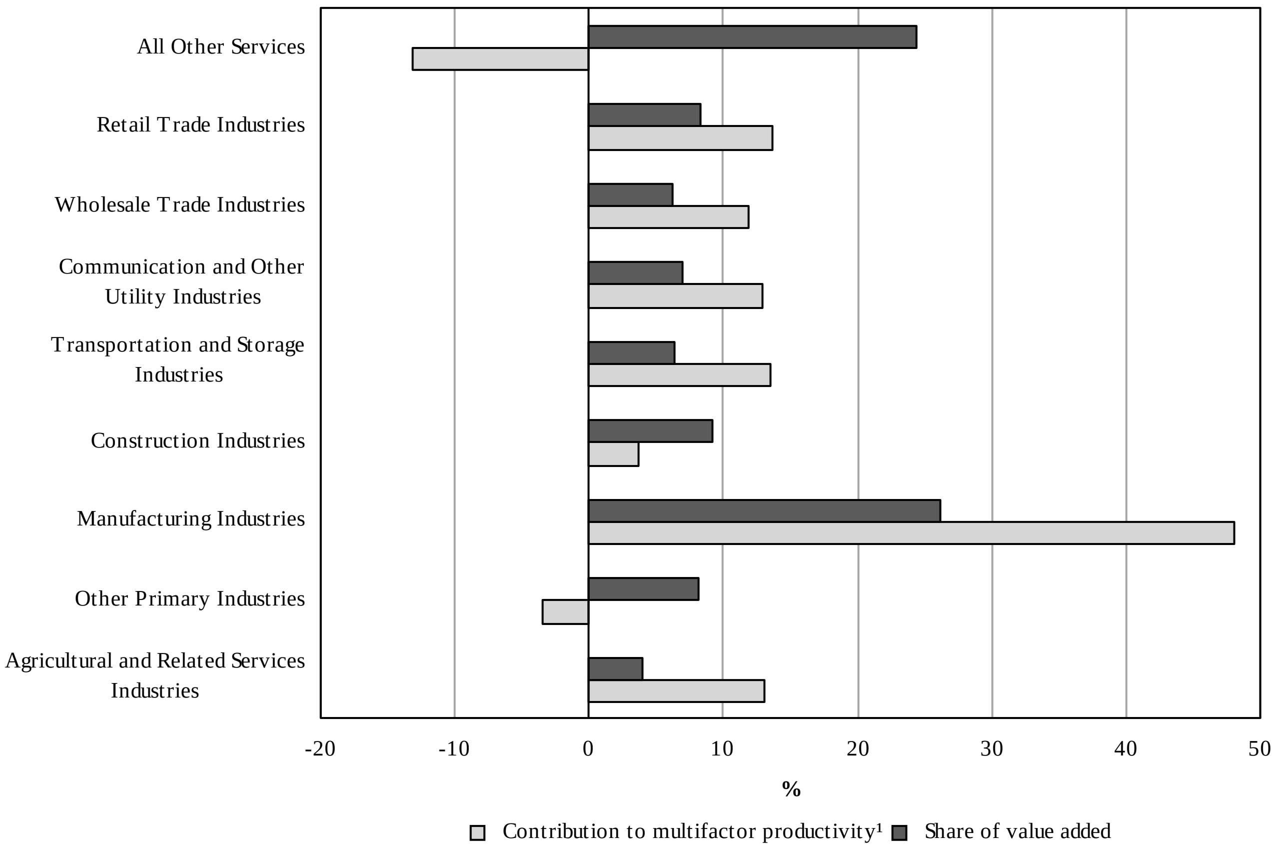
Manufacturing made the most important contribution to aggregate productivity growth over the entire period (48%), though it should be noted that it also accounts for the largest share of value added. Other high productivity growth sectors made less of an overall contribution to productivity growth simply because they are relatively smaller sectors—namely, agriculture, transportation, communications, wholesale and retail.

A better measure of the relative contribution of a sector is the percentage contribution made to aggregate productivity growth divided by the relative size of the sector. Using this measure, the most important sector was agriculture with 3.3, followed by transportation at 2.1, and wholesale, communications, and manufacturing at 1.9, 1.8, and 1.8 respectively.

1.6 Is labour productivity growth always synonymous with growth in the standard of living?

Productivity growth is generally regarded as synonymous with growth in the amount of real GDP produced per capita. Growth in real GDP per capita is often used as a measure of the standard of living.

Figure 1.6 Industry contribution to productivity growth, 1961-1995



Note: 1. Based on value-added.

However, there are periods in which movements in the growth in labour productivity (output per hour) and the growth in the standard of living (output per capita) have not been coincident. The two measures differ primarily in terms of the denominator used. The former uses hours and the latter uses population. Conceivably, productivity can increase and standards of living can fall or stagnate over periods as long as a decade if increases in jobs do not reflect growth in the population. Over the period 1961-1999, the growth in real GDP per capita has generally tracked the growth in labour productivity (Figure 1.7). However, the two measures diverged from one another in the mid-1980s and the 1990s. In particular, the growth in real GDP per capita exceeded labour productivity growth in the 1980s, but then fell back relative to the growth in labour productivity in the 1990s.

The rate of growth in Canadian real GDP per capita in the 1990s (1988-1999) was less than a third of its growth rate in the 1980s (1979-1988). Yet the productivity performance of the Canadian economy has been relatively stable over the two periods. This has posed a conundrum: how is it possible for Canada to do relatively well in one measure and poorly in the other?

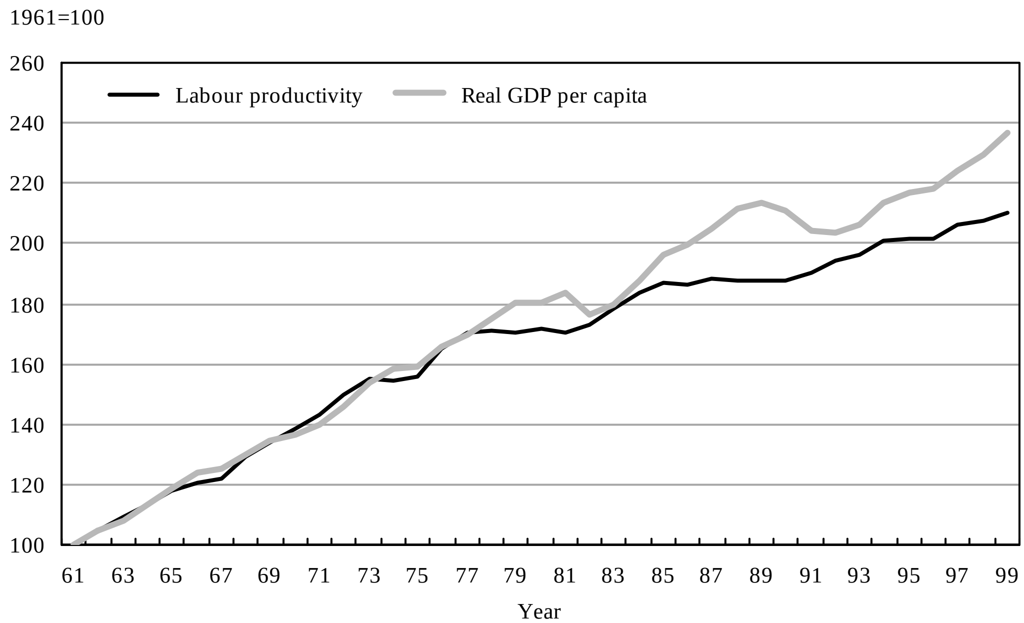
In order to explain how this can occur, it is useful to consider the inherent differences in the way the two measures are constructed.

The standard of living measure (real GDP per capita) differs in several respects from the labour productivity measure, though it is linked via an identity. By construction,

Real GDP per capita = (Real GDP/hours worked) * (hours worked/job) * (jobs/potential labour force) * (potential labour force/population) (3)

This identity means that the growth rate in real GDP per capita is just equal to the sum of the growth rates in labour productivity (the first term on the right-hand side) plus the rates of growth of the other three terms. Thus, growth in the standard of living can increase at a different rate than that of labour productivity if there are any changes in the other three terms, namely, hours worked per job, the ratio of those with a job to those who might take a job (a type of employment rate), or the ratio of the population that might take a job to the total population (a type of participation

Figure 1.7 Cumulative growth in labour productivity and real GDP per capita compared, 1961-1999



rate). The rates of growth in real GDP per capita and output per hour worked can diverge substantially during periods when the product of the employment rate, the participation rate, and the average hours worked variable is either increasing or decreasing.

Figure 1.8 indicates notable differences in the growth rates of the various components mentioned above.[8] Between the late 1980s and the mid-1990s, the growth in real GDP per capita fell while the growth in real GDP per hour worked (labour productivity) remained relatively constant. The difference between the two in each decade could have arisen from differences in any of the other components of equation (3).

In both decades, Canada experienced relatively similar increases in the percentage of the working-age population (15 and over) and relatively constant decreases in the hours worked per job. Since the rates of growth of these two variables have not changed substantially over the two decades, neither explains the decline in the growth in real GDP per capita relative to the growth in productivity.

The cause of this decline is the decrease in the number of people holding jobs relative to the population that can take jobs. While this ratio increased in the 1980s, it fell in the early 1990s. Thus, growth in real GDP per capita decreased despite the relative constancy in growth of real GDP per hour because employment growth did not keep up with population growth. This could have occurred because Canadians increasingly chose not to take jobs—for example, by taking early retirement—or because not enough new employment opportunities were created to handle the increasing population.

The Canadian experience can be examined in more detail by looking at these rates of change over a longer period going back to the late 1960s (Figure 1.9). For the sake of presentation, the terms 'jobs/age 15 and over' and 'age 15 and over/population' are replaced in Figure 1.9 with their product—the jobs-to-population ratio.

There are substantial cyclical variations in the various components. Real GDP per capita and the jobs-to-population ratio both declined substantially in the early 1980s and the early 1990s, when the Canadian economy suffered a recession. But during the mid-1980s, the jobs-to-population ratio experienced positive growth after one year of precipitous decline in 1982, thereby allowing the positive growth rates in real GDP per hour to be amplified into even higher growth rates in real GDP per capita during this period. This led real GDP per capita to increase above the long-run trend in labour productivity (Figure 1.7). However, the 1990s were quite different from the 1980s. The early 1990s experienced not just one but several years of dramatic decline in the jobs-to-population ratio, whose cumulative effect was substantial. Moreover, the subsequent growth in this ratio was weaker than in the 1980s and by 1999 was not sufficient to offset the declines of the early 1990s recession.

[8] GDP here includes both government and private sector output.

Figure 1.8 Average annual growth from peak to peak for the last two business cycles

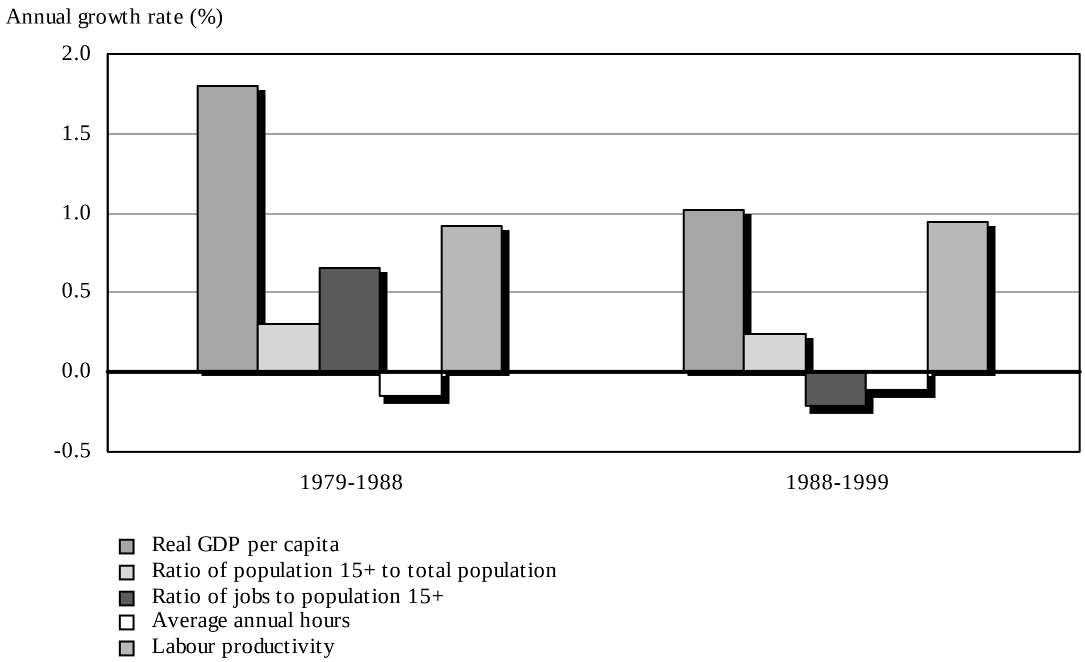


Figure 1.9 Annual growth rates in real GDP per capita, real GDP per job and jobs-to-population ratio, Canada

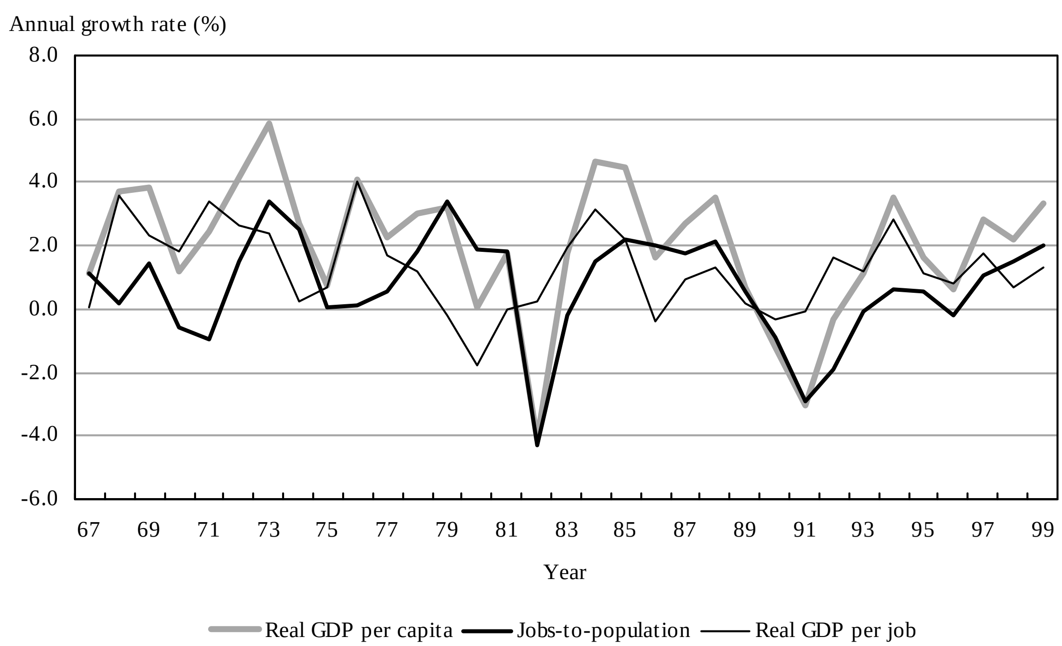
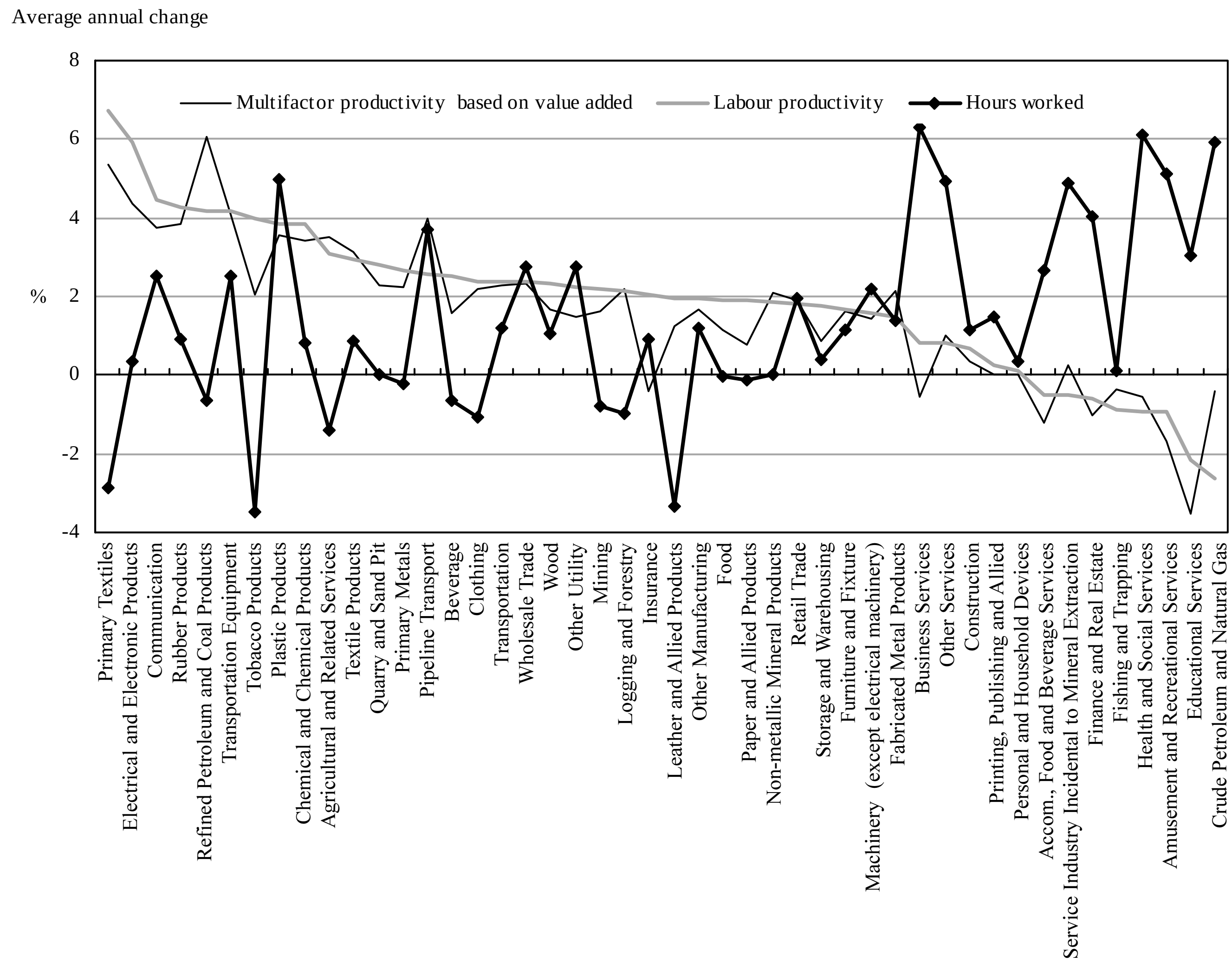


Figure 1.10 Annual rate of growth in multifactor productivity, labour productivity and hours worked by industry[1], 1961-1996



Note: 1. Ranked by labour productivity growth rates.

1.7 Employment growth and productivity

Productivity growth is sometimes seen to be at odds with a society's employment objectives. Firms that increase their productivity are seen to do so by decreasing the amount of employment required per unit of output. Whether reductions in employment requirements per unit of output also reduce overall employment depends on a number of factors.

If efficiency gains are passed on to consumers as lower prices, then output should increase. How much it increases will depend on how responsive consumer demand is to price reductions (the price elasticity of demand). If it is extremely responsive, output may increase sufficiently to offset the decrease in employment brought about by decreases in employment per unit of output. The net result could be an increase in total employment.

Perhaps more importantly, productivity gains originate in technical progress that arises from innovation—innovation that results from the introduction of new products and processes. At any point in time, this innovation affects firms that are at different points in their life cycle in different ways. Those firms that are at a more mature stage are often characterized as being involved in more process innovation, where innovation focuses on the reduction of costs by a reduction in unit labour requirements. But at the same time, new technologies are allowing the establishment of new firms. The creation of new firms leads to new jobs. In any industry then, technological change is leading some firms to create new jobs and others to reduce their employment requirements. At the industry level, the net effect of productivity gains on employment is difficult to predict.

In order to investigate the relationship between productivity growth and employment growth, the growth in multifactor productivity and labour productivity is compared to the growth in hours worked across 46 industries[9] over the period 1961-1996. Figure 1.10 plots the multifactor productivity growth rate (based on value added), the labour productivity growth rates, and the growth in hours worked. In Figure 1.10 industries are ranked from left to right by the average labour productivity growth rate. The correlation coefficient between multifactor productivity and hours worked is negative (-0.41). However, multifactor productivity is difficult to measure in some sectors such as crude petroleum and natural gas, finance and real estate, business services and amusement and recreational services. If we exclude these and examine only the top 35 industries in terms of productivity growth, the correlation drops to (-0.11). If just the manufacturing sector is examined, then the correlation approaches zero. In conclusion, when only a subsample of industries that are less affected by measurement problems is used, there is no significant relationship between multifactor productivity growth and the growth in hours worked.

If labour productivity rather than multifactor productivity growth is used and the same exercise is performed over the period 1961-1996, we find a stronger negative correlation (-0.53) between labour productivity growth and growth in hours worked at the industry level. Moreover, when we examine only the top 35 industries, the correlation in this case remains negative and significant at (-0.32). As mentioned in section 1.2, labour productivity is just the sum of multifactor productivity growth and a term that depends upon the capital/labour intensity of an industry. Since the correlation coefficient between multifactor productivity growth and growth in hours worked was lower than with labour productivity growth, this means that the stronger negative relationship between labour productivity and employment is being partly driven by increases in the capital-to-labour ratio.

In industries where labour productivity is increasing because of increases in capital per worker, employment is increasing at a slower rate, or actually decreasing. It is therefore not the measure of disembodied technological change that is being captured by the multifactor productivity measure as much as the factors that have led to a capital deepening (a substitution of capital for labour) that have had a negative impact on job growth at the industry level.

References

Cas, A. and T.K. Rymes. 1991. *On Concepts and Measures of Multifactor Productivity in Canada—1961-1980*. Cambridge: Cambridge University Press.

Denny, M. and T.A. Wilson. 1992. "Productivity and growth: Canada's competitive roots." *Productivity, growth and Canada's international competitiveness*. T.J. Courchene and D.D. Purvis, (eds). Bell Canada Papers on Economic Policy, Proceedings of a conference held at Queen's University, September. 7-58.

Galarneau, D. and J.-P. Maynard. 1995. "Measuring productivity." *Perspectives on Labour and Income* (Statistics Canada Catalogue no. 75-001-XPE). 7,1: 26-32.

Wells, J.S., J. R. Baldwin and J.-P. Maynard. 1999. "Productivity growth in Canada and the U.S." *Canadian Economic Observer* (Statistics Canada Catalogue no. 11-010-XPB). 12, 9: 3.1-3.9.

[9] This is essentially the M-level of aggregation used in calculating productivity measures by the Productivity Group of the Microeconomic Analysis Division.

2 Restructuring and Productivity Growth in the Canadian Business Sector

JOHN R. BALDWIN, RENÉ DURAND AND JUDY HOSEIN

2.1 Introduction

This chapter examines the pattern of structural change in the Canadian economy and how it relates to productivity growth.[1] Structural change occurs when the relative importance of various sectors increases or decreases, or when the share of output produced by a given sector increases. In turn, this occurs when the sector's growth rate exceeds that of the economy as a whole.

In this chapter, we address two main issues. The first is the extent to which Canada has been shifting production away from sectors with low productivity to those with higher productivity. The second is the way in which productivity gains have brought about changes in the importance of different sectors. The first issue treats structural change as exogenous and asks only whether restructuring tends to enhance overall productivity. The second asks whether and how productivity growth influences structural change.

Aggregate productivity is just the weighted average of the productivity of individual sectors (Domar 1961). Some economies are heavily concentrated in industries that are highly productive, others in industries that are less productive. Changes that occur over time in the structure of an economy may increase the relative importance of the more productive sectors or they may do the reverse. If an economy shifts production and employment from those sectors that are less productive to those that are more productive, then aggregate productivity will increase. Explanations for lack of productivity growth are sometimes based on the notion that an economy has an inappropriate industrial structure or that structural change is not supportive of overall productivity growth. Attempts to understand the reason for growth, or the lack thereof, in aggregate productivity cannot ignore the effects of restructuring.

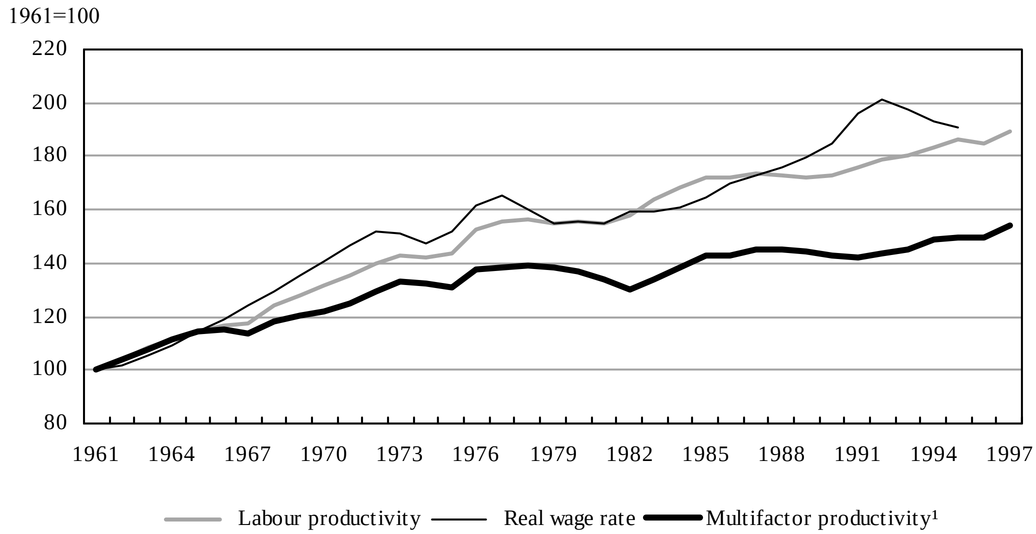
In turn, restructuring does not occur independently of productivity change. Productivity growth may influence the industrial structure in two different ways: directly via changes in relative prices, and indirectly via changes in relative wage rates. If differential productivity gains at the industry level are passed on to consumers via relative price changes, productivity will affect the relative demand for products at the industry level through its direct effect on relative prices. The magnitude of this effect will be determined by the relative size of the price elasticity of different markets.

Productivity growth may also influence the structure of industry demand by differentially affecting factor incomes. Productivity gains may be passed on to workers through nominal wage rate change, with some workers experiencing greater wage gains as a result of their industry's superior productivity gains. This may affect the industrial structure if the income elasticity of demand by workers in different industries is not the same and, as a result, increases in demand due to changing relative wage rates affect industry outputs differentially.

The chapter proceeds as follows: the first section examines whether structural shifts in the Canadian economy have enhanced the importance of the more productive sectors. The second section focuses on how productivity growth is reflected in relative prices, relative nominal wage rates, and relative quantities of different industries. In so doing, it investigates how productivity growth affects the structure of the economy.

[1] In this chapter, productivity estimates are based on gross output, intermediate inputs and primary (capital and labour) inputs. All indices are chained Fisher ideal indices based on annual data.

Figure 2.1 Cumulative growth in labour productivity, multifactor productivity and the real wage rate, Canadian business sector



Note 1: Based on value-added.

2.2 Measures of productivity growth in Canada

Growth in productivity can be measured using either labour productivity or multifactor productivity (MFP). Labour productivity is measured by output per hour worked and changes in labour productivity are derived from changes in output relative to changes in number of hours worked. MFP growth estimates are derived from the difference between the rate of growth of real output of the business sector and the combined rates of growth of labour inputs and other inputs used in that sector.[2]

Productivity measures are used to capture improvements in an economy's productive capability or efficiency. As such, growth in labour productivity captures the extent to which a given increase in labour inputs increases output. MFP growth measures output change relative to the changes in a larger bundle of inputs—labour and capital when value added is used as a measure of output, and labour, capital, materials and energy when gross output is used as a measure of output. Multifactor productivity growth, calculated using value added, is just the weighted sum of the growth in labour and capital productivity, where the weights are the share of labour and capital in total output (see Chapter 1).

Productivity measures are also used to measure the sources of growth. Growth in labour productivity arises either because of increases in capital intensity or because of technological change. If the objective is to measure the effect of just technological change, labour productivity measures are seen to be inferior to MFP measures because they do not capture only technological change. As pointed out in Chapter 1, the rate of growth of labour productivity is the rate of growth in multifactor productivity plus the rate of growth in the capital-to-labour ratio (the amount of capital available per hour) multiplied by the share of output going to capital. Labour productivity can then increase if the capital-to-labour ratio increases.

Measures of multifactor productivity remove the effect of changes in other measured inputs such as capital. In doing so, they provide a measure that is generally regarded as coming closer to the pure measure of technological change than growth in labour productivity measure.[3] Despite this advantage of the MFP over the labour productivity measure, the growth in labour productivity continues to be closely examined because of its relationship to changes in wage rates.

Figure 2.1 depicts the course of multifactor productivity growth, labour productivity growth,[4] and changes in the

[2] Multifactor productivity can be calculated using either gross output or value added as a measure of output. In the first case, the inputs considered are labour, capital and materials. In the latter, just labour and capital. See Appendix 1 for further details.

[3] Even here, the type of measure that is used in this study can be further refined to better understand the components of productivity growth. Recent work has attempted to break down simple measures of MFP and to remove from them the contribution of economies of scale and the capacity utilization (Morrison 1992). Chapter 8 contains the results of such an exercise for Canadians in manufacturing industries.

[4] The measures of both MFP and labour productivity make use of the value added concept of output.

Table 2.1 Restructuring in the Canadian business sector, 1961-1995						
Sector	GDP share 1961 (1)	GDP share 1995 (2)	Hours worked share 1961 (3)	Hours worked share 1995 (4)	Relative labour productivity 1961 (5)	Relative labour productivity 1995 (6)
	%				ratio	
Primary Textile Industries	12.7	8.9	19.4	7.7	0.7	1.2
Manufacturing	29.4	25.3	26.0	19.3	1.1	1.3
Construction	9.3	7.0	10.2	8.5	0.9	0.8
Transportation and Communications	13.5	13.7	9.2	9.3	1.5	1.5
Wholesale and Retail	14.8	14.5	18.2	21.9	0.8	0.7
Finance, Insurance and Real Estate	10.5	13.1	3.8	6.6	2.8	2.0
Business Services	2.0	6.3	1.7	8.6	1.2	0.7
Health and Education	1.5	3.5	0.8	3.5	1.9	1.0
Other Services	6.2	7.7	10.6	14.5	0.6	0.5

Note: Columns 5 and 6 are estimated by dividing column 1 by 3 and column 2 by 4, respectively.

real wage rate in the Canadian business sector, from 1961 to the mid-1990s.[5]

Productivity growth slowed dramatically during the post-1973 period compared to the pre-1973 period. Multifactor productivity grew at approximately the same rate in the (peak-to-peak)[6] period 1988 to 1997 (0.7%) as in the earlier period from 1973 to 1979 (0.6%). However, productivity growth remains well below that posted during the period 1961 to 1973, when it averaged over 2.3% per year.

Labour productivity growth has been faster than multifactor productivity growth since the capital-to-labour ratio has generally increased over time. The growth in labour productivity, in the long run, closely mirrors the growth in real wages. Over the entire period, the annual growth rates of value added per hour worked and the real wage rate were 1.8% and 1.9%, respectively.

2.3 Patterns of restructuring

The Canadian business sector has been shifting out of goods production into services over the last 40 years (Table 2.1, columns 1 and 2). Between 1961 and 1995, the share of business sector GDP fell by 3.8 percentage points in the primary goods sector, by 4.1 percentage points in manufacturing, and by 2.3 percentage points in construction. On the other hand, the share of business sector GDP in the finance, insurance and real estate sector rose by 2.6 percentage points, and in business services by over 4 percentage points over the same period (Table 2.1).

The share of hours worked has also generally declined in the goods sector and increased in the service sector (Table 2.1, columns 3 and 4). But the decline in the share of hours worked is generally greater than the decline in the share of GDP in each of these sectors. As a result, the relative output per hour worked[7] of the goods sectors (Table 2.1, columns 5 and 6) has generally increased in the sectors that were declining in importance.

It is the relationship between these structural shifts and the productivity of these sectors that catches the attention of observers who ask whether the pattern of structural change has enhanced aggregate productivity growth.

2.4 Patterns of structural change

Structural change can improve or decrease aggregate labour productivity even when the productivity of different sectors remains constant. This is because aggregate labour productivity is the weighted average of the productivity of individual sectors.

Aggregate labour productivity (Q/L) is calculated as

$$\frac{Q}{L} = \sum_i w_i \cdot \left(\frac{q_i}{\ell_i}\right)$$

where Q is aggregate output, L is aggregate labour input, q_i is the output of sector i, and l_i is the labour input of sector i and,

[5] The real wage rate here is measured by an index of nominal wages per hour worked divided by an index of the prices of manufactured and non-manufactured gross outputs.
[6] The Canadian economy was still in its expansion phase at the end of 1997 and therefore, the estimates for 1988-1997 do not cover a full economic cycle.
[7] This is calculated as the share of GDP divided by the share of hours worked.

Table 2.2 Correlation between structural change and productivity[1]

	Change in relative industry size 1961-1995 (hours worked)	Change in relative industry size 1961-1995 (% of GDP)	Labour productivity growth 1961-1995	Multifactor productivity growth 1961-1995
	correlation coefficient			
Relative industry size (1961 share of hours worked)	-0.40		-0.002	
Relative industry size (1961 share of GDP)		-0.47	-0.003	0.07
Labour productivity growth (1961-1995)	-0.27	-0.25		
Multifactor productivity growth (1961-1995)	-0.27	-0.26		
Relative labour productivity in 1961	0.06	0.24	-0.23	0.11

Note: 1. M-level industries, except owner-occupied dwellings.

$$w_i = l_i / L$$

Changes in the share of a sector as measured by w_i will affect the aggregate labour productivity even if the labour productivity of each sector remains constant.

To understand the pattern of shifts that has taken place and its effect on productivity growth, data on structural change and productivity growth over the period 1961-1995 are examined at a level of disaggregation that has 46 industries.[8]

The relationship of growth to initial size of the sector

Initially, correlations between the structure of the economy (the relative size of the different sectors) and changes therein (changes in the relative size) are examined. Relative size is measured, on the one hand, by the share of current GDP and, on the other hand, by labour inputs as represented by the share of hours worked. Changes in relative size are measured as the percentage point changes in their share. We examine the changes in share because these variables determine whether structural shifts by themselves will contribute to changes in productivity. The sign of the correlation between size at the beginning of the period and changes in size tell us whether the largest sectors are getting larger or whether the opposite is occurring (Table 2.2).

The correlations between changes in the output share of an industry and its initial share are negative. The sectors that were initially largest have declined in importance, whereas the smaller sectors have increased in importance. Structural shifts, therefore, have evened out the distribution of both output and labour inputs over time. This indicates that the structural change that took place diversified the economy out of traditional areas.

The relationship of sectoral growth to initial labour productivity

It is also of interest to know whether restructuring has moved resources out of sectors that are relatively unproductive and into sectors that are relatively more productive. Are structural shifts concentrated in those sectors that initially had higher labour productivity? In other words, did the sectors that started off with high labour productivity expand?

It should be noted that for this exercise the level of labour productivity and not its growth rate is used. When interpreting the correlations between structural changes and this measure of industry productivity, it must be kept in mind that the measure of the level of labour productivity of an industry is influenced by the capital intensity of a sector. Sectors with higher output per hour tend to be those with higher capital-to-labour ratios and with higher wage rates. Since differences in labour productivity can be caused by differences in capital intensity as well as more fundamental disparities in productive capability or efficiency, structural change that is closely associated with levels of industry labour productivity differentials may indicate that the economy is moving resources into industries that are either more technologically advanced or more capital intensive.

To examine the relationship between structural shifts, changes in a sector's share of outputs or inputs over the period 1961 to 1995 are correlated with the relative labour productivity of a sector in 1961. The latter is measured by the ratio of the share of nominal GDP to the share of hours worked for each industry. A positive correlation between share change and initial productivity indicates that there was a general tendency for those sectors that expanded to have a higher labour productivity and for those sectors that contracted to have a lower labour productivity.

8 See Appendix 2 for a list of the industries.

There is a weak tendency for the share of GDP in a sector to increase where initial-year labour productivity was larger. The correlation between a sector's share of GDP and its relative labour productivity in 1961 was 0.24. This indicates that the industry structure has shifted toward industries that initially exhibited higher labour productivity.

There is an even weaker positive relationship between the relative labour productivity of a sector at the beginning of the period and changes in importance of the sector as measured by its share of employment (hours worked). The correlation coefficient between these two variables was 0.06 (Table 2.2).

Restructuring has tended to slightly increase industry output and employment shares in industries that initially had a higher value added per hour worked.

The relationship of sectoral growth to productivity growth

It is also of interest to know whether those sectors that are increasing in relative size had higher productivity growth. Aggregate productivity growth is the weighted average of sectoral productivity growth. If productivity growth is higher in those sectors that are increasing in importance, this will have a beneficial impact on overall productivity growth.

The correlation between the change in the shares of GDP and MFP growth is negative (-0.26). So too is the correlation between changes in labour shares and labour productivity growth (-0.27). Thus the sectors that increased in importance had lower productivity growth.

The impact of these changes on overall productivity growth has been substantial. If the labour productivity growth of individual sectors is weighted by their 1961 labour share, average labour productivity growth over the period 1961 to 1995 is 1.85%. If it is weighted by 1995 average labour shares, it is 1.39%. The decline in the growth of average labour productivity as a result of the reweighting is about 25%.

The final question addressed is whether labour productivity growth was related to initial labour productivity levels. Is it possible that those sectors that initially had higher labour productivity were those whose labour productivity growth was fastest? Or was there a catch-up effect in that those sectors that were behind, grew most rapidly. The latter is the case, at least for growth in labour productivity, since there is a negative though not significant correlation (-0.23) between the growth in labour productivity and the initial labour productivity of a sector. On the other hand, there is a positive though not statistically significant correlation coefficient between multifactor productivity growth and the initial value of labour productivity.

In summary, restructuring had the following characteristics:

1) The sectors that were largest at the beginning of the period declined in relative importance.

2) The sectors that had higher labour productivity at the beginning of the period did not tend to increase their labour productivity most rapidly, but there was a weak tendency for them to experience faster multifactor productivity growth.

3) Overall, growth in a sector's importance was negatively correlated to growth in labour productivity and to growth in multifactor productivity, but these relationships were sufficiently weak that it is appropriate to conclude that growth in productivity was not significantly related to changes in a sector's importance.

All of this suggests that changes in a sector's importance did not respond closely to differences in sectoral productivity growth.

2.5 Productivity growth and its effect on structure

The finding that changes in industry structure are not closely related to productivity growth should not be interpreted to mean that industry differences in productivity growth had little effect on the structure of the economy. It only shows that restructuring *per se* did not contribute to our aggregate productivity growth.

This section investigates the way in which productivity growth affects key variables that in turn determine industrial structure. Productivity growth might be expected to influence both prices and wages. In competitive markets, productivity gains are passed to consumers via price changes. Industries where productivity grows relatively quickly should therefore see their prices fall faster (or grow less quickly) than industries where productivity grows less quickly. Factor inputs may be differentially affected as well. Labour may see its remuneration increase as a result of productivity improvements. In this case, differential rates of productivity across industries will be accompanied by differential rates of change in wages.

Table 2.3 Correlation between relative multifactor productivity growth and selected variables across 46 Canadian business industries, 1961-1995

	Price inverses	Nominal GDP	Hours worked	Multifactor productivity	Gross output	Relative real wages
			correlation coefficient			
Price inverses	1.00	-0.24	-0.18	0.80	0.34	0.83
Nominal GDP	-0.24	1.00	0.85	-0.11	0.82	-0.26
Hours worked	-0.18	0.85	1.00	-0.18	0.65	-0.38
Multifactor productivity	0.80	-0.11	-0.18	1.00	0.35	0.83
Real gross output	0.34	0.82	0.65	0.35	1.00	0.15
Relative real wages	0.83	-0.26	-0.38	0.83	0.15	1.00

In order to examine whether it is input or output prices that benefit from productivity growth, this section asks whether differential productivity growth is reflected in differential changes in prices and wages across industries over the period of study. It also examines the shifts in the distribution of economic activity across industries (real output and nominal output shares) and their relationship with productivity growth for 46 industries.

Productivity growth and the structure of output prices in the economy

Multifactor productivity growth affects an industry's share of output by influencing its relative output prices and quantities. Over time, an industry's relative output price changes should reflect both relative productivity differences and relative factor-price changes.

Whether output price changes fully reflect productivity changes will depend upon the level of competition in an industry. The greater the intensity of competition, the more likely it is that cost reductions that are facilitated by productivity improvements will be passed on to consumers.

Whether relative output price movements of an industry just reflect productivity change will also depend upon whether the relative prices of factor inputs, like labour, also change and how important these factor costs are to an industry. If input markets are highly competitive and factors are mobile, factor prices will tend to equate across industries. As a result, cross-industry differences in the growth in relative factor prices (such as wage costs) will be small, and inter-industry differences in productivity growth will mainly be reflected in relative output price changes.

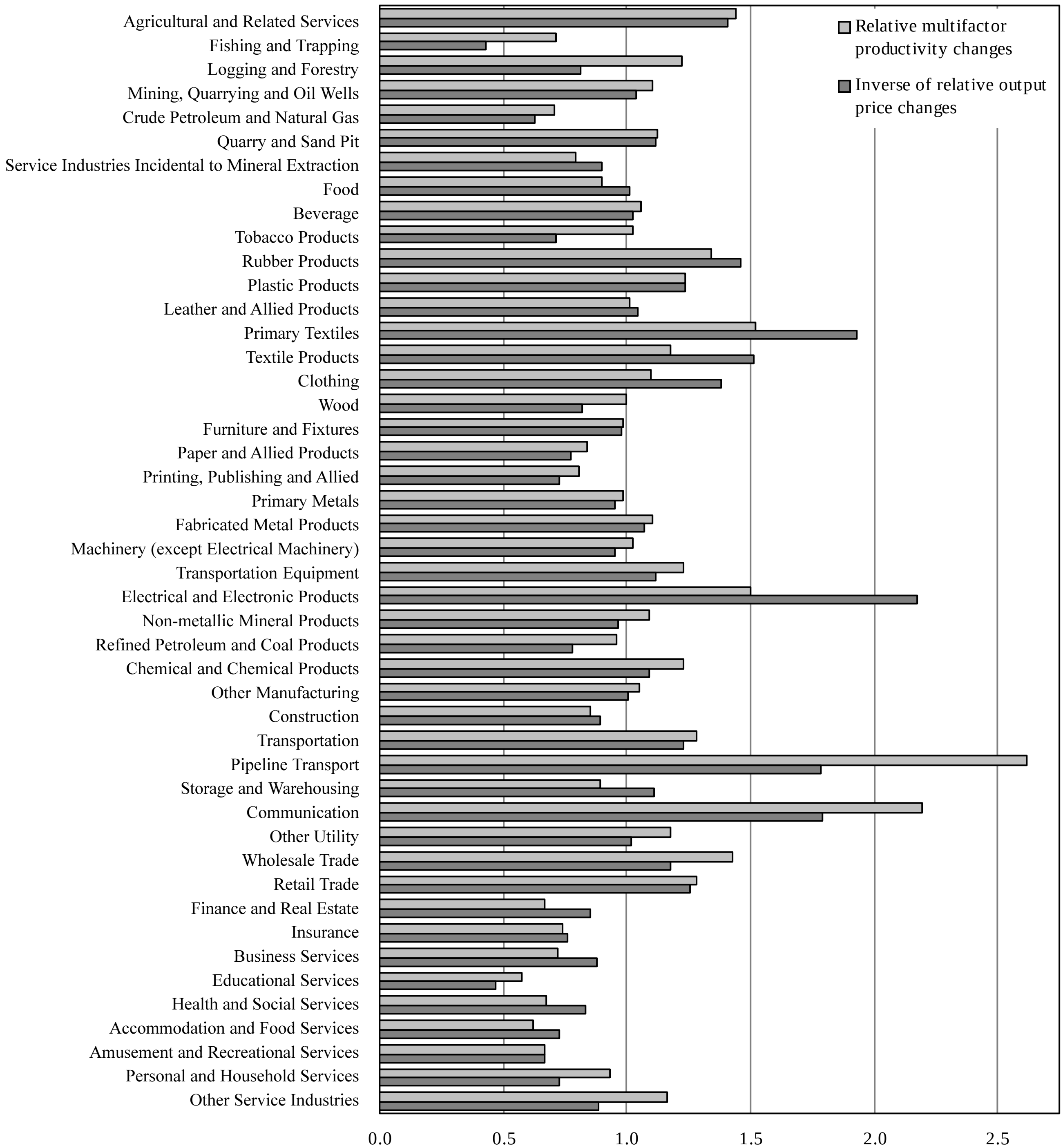
In order to investigate this relationship, the relative multifactor productivity growth is compared to the inverse of the relative output price changes of 46 industries over the 1961-1995 time period (Figure 2.2). Relative productivity growth is calculated as the productivity index of each industry divided by the aggregate productivity index. If an industry's average productivity growth over the period exceeds the average for the business sector, its relative productivity value is greater than 1; conversely, if it is below 1, then its productivity growth is less than average. Similarly price indices are normalized by dividing industries' price indices by the aggregate price index for the business sector. Since a negative correlation between price changes and productivity growth is expected, the inverse of this relative price change is then plotted in Figure 2.2 for ease of exposition.

Relative price changes and relative productivity growth are strongly related. The correlation between productivity growth and the price inverse is 0.80 (see Table 2.3). The relationship between the relative price changes and productivity growth across industries suggest that competition works to incorporate productivity changes in price changes. Industries with relatively high productivity growth rates (significantly above 1 in Figure 2.5) are also those whose output prices fall relative to the aggregate price deflator (the inverse of their relative price change is significantly above 1 in Figure 2.5). In conclusion, important productivity growth differentials across industries are reflected in changes in the general price structure over the long run.

Productivity growth and wages

Predictions about the effect of productivity growth on wage rates depend on assumptions made about the nature of competition in labour markets and the extent to which labour is mobile across industries—the extent to which workers will move from low-paying to high-paying industries in response to wage differentials and thereby equate wages paid across industries.

Figure 2.2 Relative productivity growth[1] and relative price changes across industries, 1961-1995



Note: 1.The productivity statistics used here are based on the gross output measure.

Under one set of assumptions, changes in relative wage rates will not reflect industry productivity differentials. If labour markets are competitive, inputs will be paid their marginal value product and if factors are mobile, similar workers will end up being paid the same wage across industries. Productivity growth then works to increase the overall marginal value product of labour and increase the overall wage rate that must be paid by all industries in an economy. Industries that do not sustain at least the average rate of productivity growth will have to increase prices to pay for ever-increasing wage rates or cut back on production and gradually die.

Under a second set of assumptions, wage rates might be expected to reflect productivity differentials. If workers manage to capture part of the superior productivity gains accruing to their industry via the collective bargaining process, wage rates will increase differentially to reflect differential productivity gains. If labour is not homogeneous and productivity growth is associated with differential increases in the quality of the labour force, wages might also be expected to increase in response to productivity growth.

In order to examine which of these two forces is stronger, multifactor productivity growth is correlated with nominal wage growth for 46 industries over the period 1961 to 1995. The correlation between these variables is only 0.07. There is only a weak link between changes in the nominal wage (defined as remuneration paid per hour worked) across industries and multifactor productivity growth (Figure 2.3). While average wage rates increase over time, they do not increase at a faster rate in those industries with faster rates of productivity growth. Higher productivity growth industries do not increase their wages faster than lower productivity growth industries.

While there is no close relationship between growth in relative *nominal* wages and growth in relative multifactor productivity across industries, there is nevertheless a very close relationship between growth in relative *real* wages and growth in relative multifactor productivity. Figure 2.4 plots the relative multifactor productivity changes of the 46 industries, ranked from left to right by the size of the productivity gains over the period. It also plots the inverse of the relative price changes, the changes in relative nominal wage rates, and the changes in relative real wage rates, where changes in real wage rates are derived by dividing the changes in nominal wages by the change in industry output prices.

From Figure 2.4, it is apparent that multifactor productivity growth and the inverse of price changes are much more closely related than are nominal wage rate changes. Indeed while there is considerable variance in the relative price changes, there is little variation in relative nominal wage changes. However, it is the case that relative changes in multifactor productivity growth are closely related to changes in the real wage rate with a correlation of 0.83 (Table 2.3). But this occurs because of the high correlation between multifactor productivity growth and industry price changes, not because of the correlation between multifactor productivity growth and nominal wage rate changes.

A previous section demonstrated that overall, the average real wage rate[9] grows at the same rate as labour productivity—suggesting that workers tend to be paid their relative marginal value product. That does not mean that above-average productivity gains at the industry level are translated into above-average nominal wage-rate changes. Productivity growth increases the real wage at the aggregate level but has little impact on the wage structure across industries.

In the Canadian economy, prices adjust to productivity growth differentials across industries. Real wages are modified as well through these very price changes. Very little adjustment, if any, in the distribution of the real wages occurs through adjustment in the distribution of nominal wages.

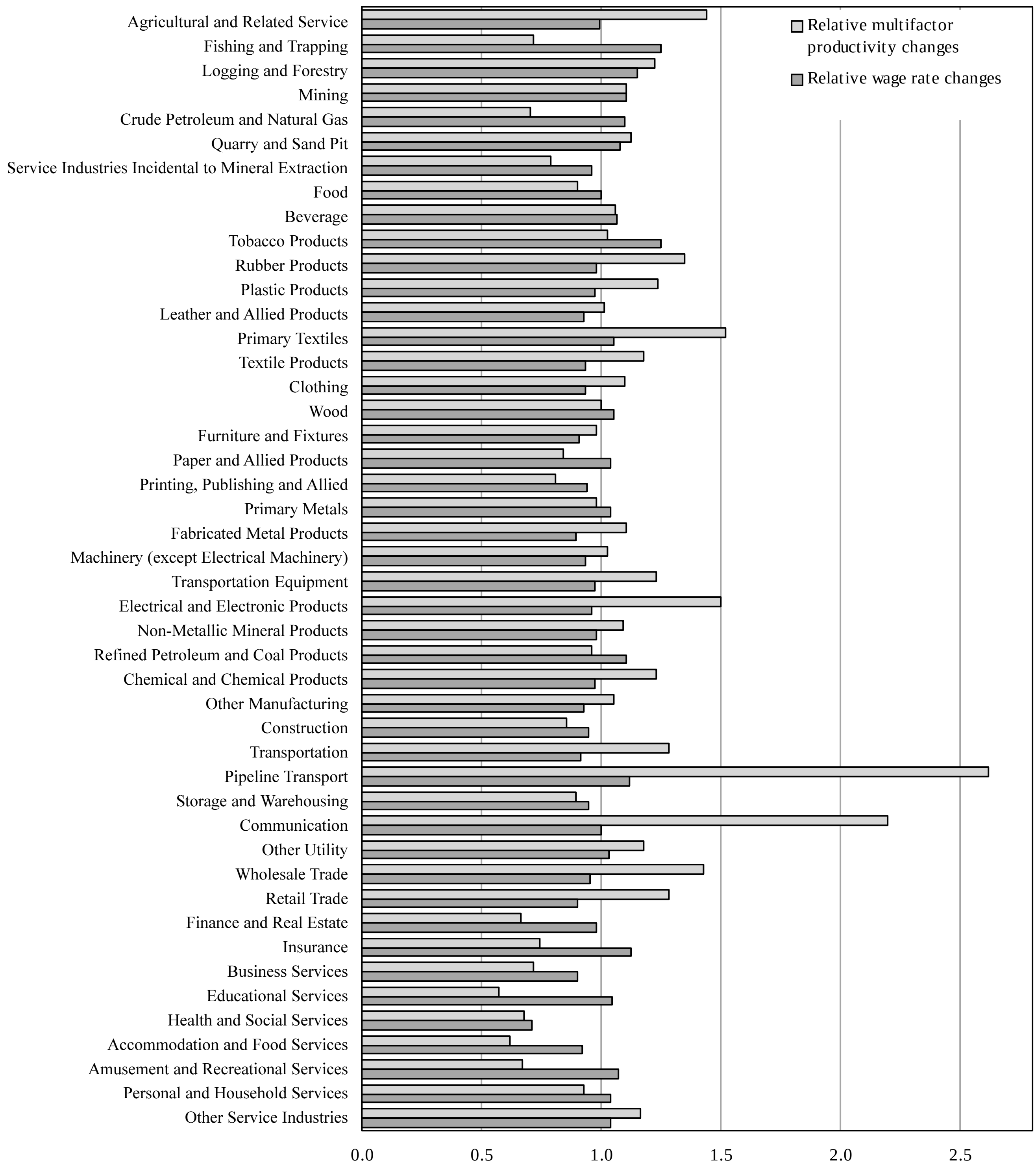
Hence, the benefits of productivity gains are largely diffused across all workers through changes in relative output prices, rather than being appropriated by the workers of the high productivity gains industries through increases in their relative nominal income.

Productivity growth and industry output shares

Changes in relative output prices, along with other factors like income that affect demand, will affect changes in relative quantities produced across industries. Relative changes in quantities will be affected by the differences in the relative prices, by variations in price elasticities, and by the extent to which changing incomes affect demand through differences in income elasticities. In turn, changes in relative prices and relative quantities will affect the relative shares of an industry or the industrial structure of the economy, since output share changes depend jointly on changes in prices and quantities. Because there are so many

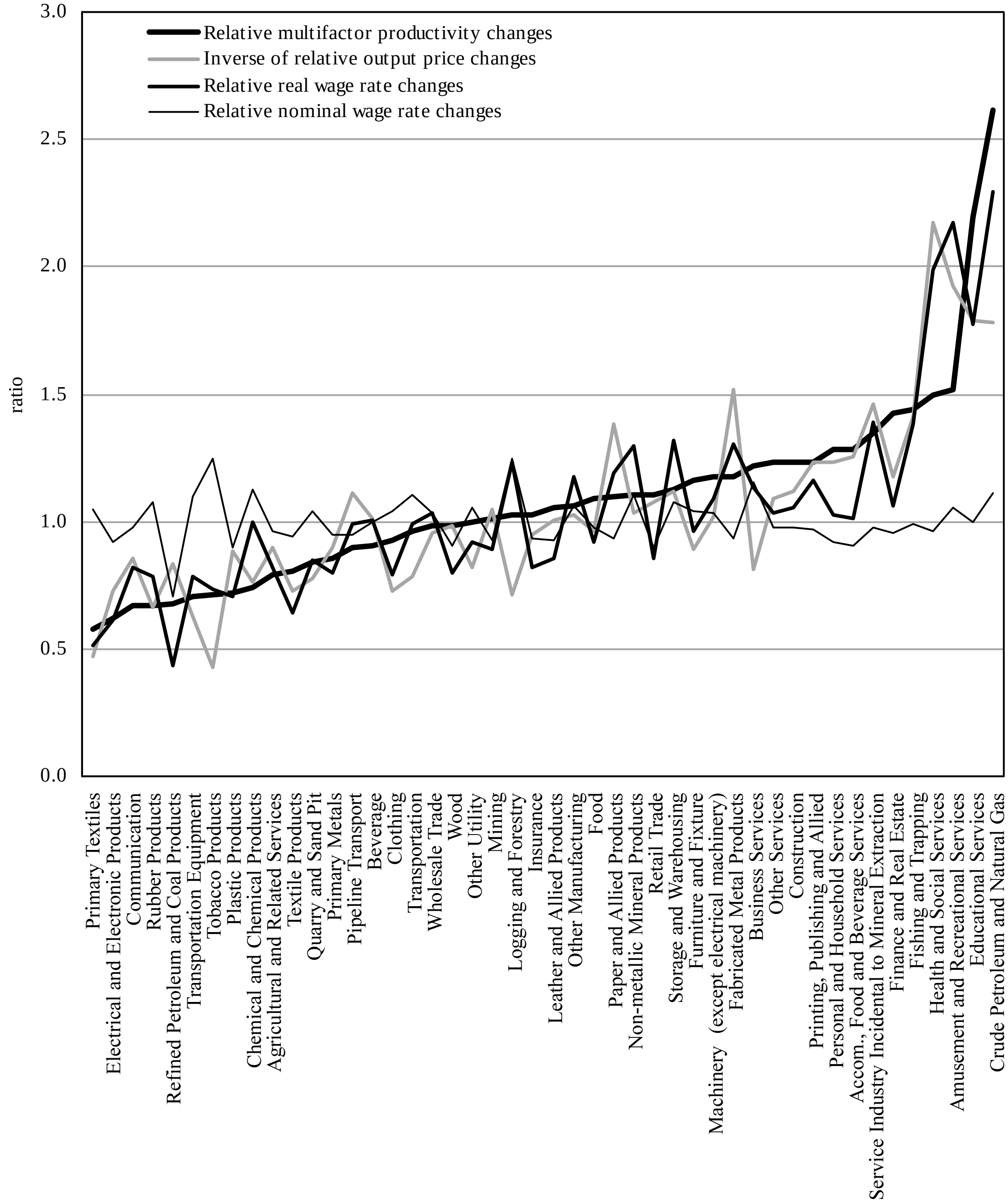
[9] Real wages, in that case, are defined by the nominal wages deflated by the aggregate price deflator rather than by each industry's output price.

Figure 2.3 Relation between relative nominal wage changes and relative productivity[1] growth across industries, 1961-1995



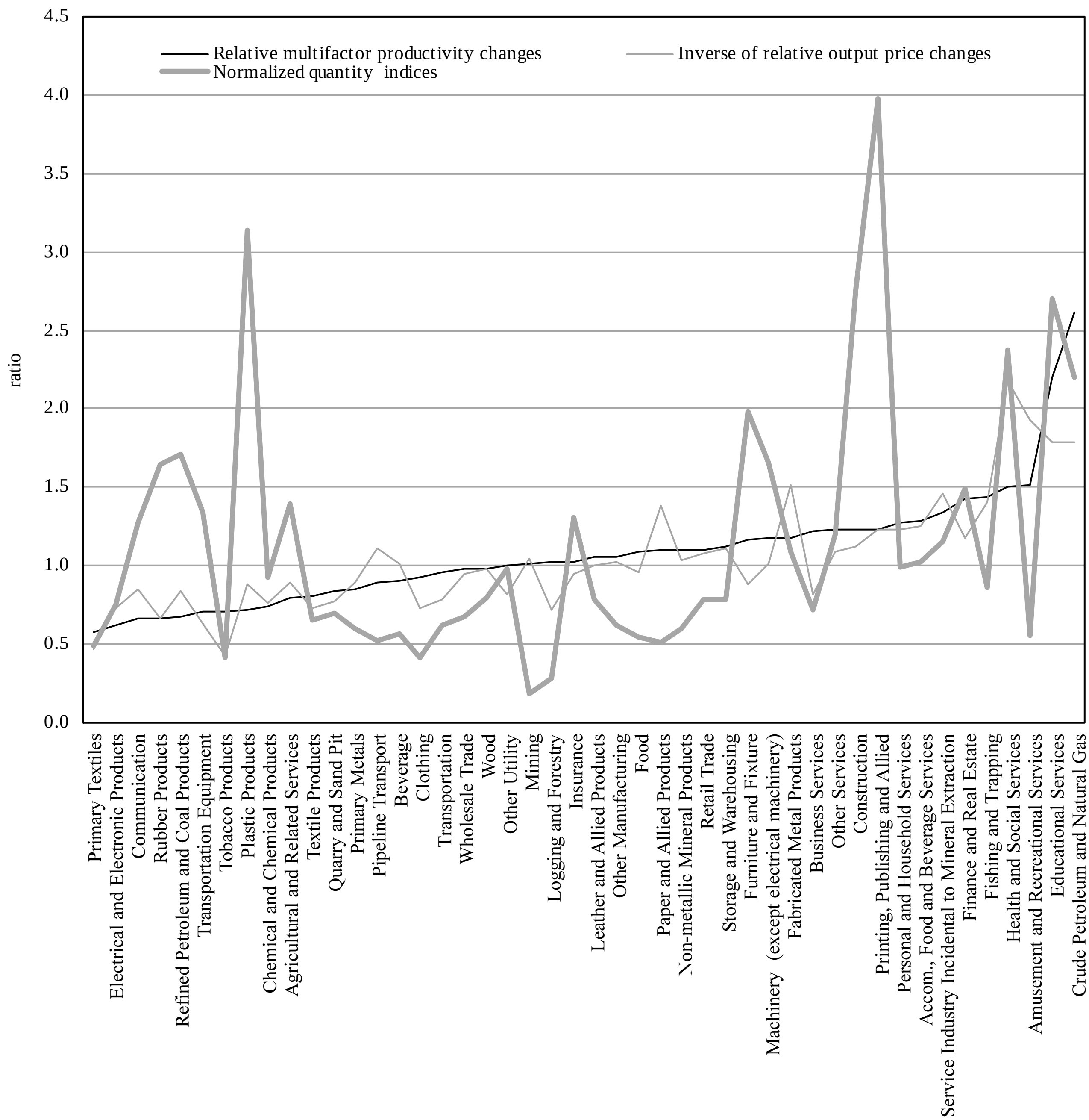
Note: 1. The productivity statistics used here are based on the gross output measure.

Figure 2.4 Relative multifactor productivity[1] growth, inverse price changes and wage rate changes, 1961-1995[2]



Notes: 1. The productivity statistics used here are based on the gross output measure.
2. Industries ranked by multifactor productivity.

Figure 2.5 Relative multifactor productivity[1] growth, inverse price changes and quantity changes, 1961-1995[2]



Notes: 1. The productivity statistics used here are based on the gross output measure.
2. Industries ranked by multifactor productivity.

factors other than price that determine demand and because price elasticities are likely to vary across industries, the relationship between multifactor productivity growth and quantity change is likely to be less than between multifactor productivity growth and price changes.

The relationship between productivity growth differentials and relative output changes across industries is depicted in Figure 2.5. While the inverse of relative price changes move closely with relative productivity, there is much less of a relationship between relative productivity growth and relative quantity growth, primarily because of the weak link between quantity change and price change. The correlation between relative quantity changes and relative price changes is -0.34 (Table 2.3). Productivity growth differentials are reflected strongly in relative price changes, but due to changing demand conditions that affect industries in quite different ways and variances in demand elasticities, relative price changes are only weakly related to relative quantity changes. The net result is that there is only a small positive correlation (0.35) between multifactor productivity growth and real gross output changes (Table 2.3).

Productivity growth differentials and shifts in nominal output share

The offsetting correlations between multifactor productivity growth and relative quantities (0.35) on the one hand and relative price changes (-0.80) on the other hand imply that productivity growth rates should not be strongly correlated with changes in industry nominal GDP. Since the correlation between multifactor productivity and price dominates, we might expect some negative correlation. This is the case since the value of that correlation was -0.11.

Despite the lack of correlation between relative multifactor productivity growth across industries and output shares, structural change has taken place. The Canadian economy has been shifting out of goods production into services over the last 40 years. Businesses, governments and households have increased their consumption of the output of the service industries over our period of study despite the relatively higher growth in the output prices of these industries. Real income growth over this period of time has shifted demand curves for services upward at a faster rate than was the case for the demand of goods-producing industries.

2.6 Summary

This chapter has demonstrated that productivity growth has affected key economic variables. Inter-industry productivity growth differentials had a substantial impact on the structure of output prices. Higher productivity growth in an industry was associated with a decline in its relative price. In turn, industries that experienced a decline in relative prices saw their relative outputs increase. However, the price effect dominates the quantity effect and multifactor productivity growth is actually negatively correlated with output share change. It is for this reason that sectors in which productivity grew most rapidly declined in terms of relative importance.

In contrast to their effect on relative prices, differential growth rates in productivity were not closely related to changes in nominal wage rates. Higher relative productivity performance at the industry level is generally not reflected in superior growth in nominal wages. The benefits of productivity growth are diffused basically through lower prices, not through higher nominal wages.

The structural shifts that have occurred in the importance of different sectors have been influenced by productivity growth. The shifts that have occurred from high-productivity to low-productivity industries that were the result of changing consumer demand have no doubt been attenuated by the effect of productivity growth on relative prices. Income elasticities or changing tastes led consumers to substitute demand away from goods to services over this period. The fact that prices fell in the goods sector relative to the services sector because of differential productivity growth rates would have attenuated the shift that was otherwise occurring. Rising income has tilted demand away from the consumption of manufactured goods to services, despite their declining relative prices brought about by higher productivity growth.

2.7 Conclusion

Canadian long-run productivity growth has followed a path that is similar to the one registered in many other industrialized countries. The strong productivity growth of the 1960s and early 1970s was followed by sluggish growth thereafter. The slowdown in productivity growth was accompanied by a slowdown in output growth.

The slowdown in productivity growth is sometimes seen to be related to structural shifts in the economy that have moved resources away from high productivity goods-producing industries to lower productivity services-producing industries. At first glance, changes in industrial structure away from high productivity industries appear to suggest that the Canadian economy did not react in a fashion that was conducive to productivity growth—that the industrial environment was not supportive of growth. It is all too easy to suggest from this that the Canadian economy did not respond to productivity growth. This is incorrect.

The question as to whether the structure of the Canadian economy helped or hindered productivity growth contains the implicit notion that a dynamic economy is one where the most productive sectors are growing in importance. It is sometimes assumed that rapid productivity growth should increase the size of a sector. This assumption is wrong for two reasons.

First, there is no reason to expect the sectors with the highest productivity growth would increase their share of total employment. Productivity growth may mean lower employment per unit of output and unless output is increased very substantially, those industries that experience the most rapid productivity growth will not increase their share of employment. In research that uses microeconomic data on plant performance, we find that plants that increase their market share also increase their labour productivity more than their compatriots but do not increase their employment share (Baldwin, Diverty and Sabourin 1995). This chapter has shown that the same is true of industries. The industries that increased their labour productivity growth the most did not increase their share of employment.

Second, there is no reason to expect that the output share of sectors that have the highest productivity growth should increase. If productivity gains are passed on to consumers, the sectors that have higher productivity gains should have greater price declines. While quantity should increase in response to price declines, there is no reason to expect that it will do so sufficiently to completely offset the price declines. This means that the relative GDP share of sectors with productivity increases may fall. In turn, this means we should sometimes expect to find a negative correlation between productivity growth and changes in GDP shares. This is what happened in Canada during the period 1961 to 1995.

This chapter has demonstrated that industry differences in productivity are not felt so much in changes in the importance of a sector as measured by GDP as in the changes in the relative prices of different sectors. Those who are seeking evidence of the effect of differences in relative productivity on the economy would be advised to seek them first in changes in relative prices and not to presume that since productivity growth and structural change are only weakly linked, this can be seen as evidence of maladjustment in the economy.

References

Baldwin, John R., Brent Diverty and David Sabourin. 1995. “Technology Use and Industrial Transformation: Empirical Perspectives.” *Technology, Information, and Public Policy*. T. Courchene (ed). John Deutsch Institute for the Study of Economic Policy. Kingston, Ontario: Queen’s University.

Domar, E. 1961. “On the Measurement of Technological Change.” *Economic Journal.* 71, p. 709-729.

Fisher, I. 1922. *The Making of Index Numbers*. Boston: Houghton Mifflin.

Morrison, C.J. 1992. “Unravelling the Productivity Growth Slowdown in the United States, Canada and Japan: The Effects of Subequilibrium Scale Economies and Markups.” *Review of Economics and Statistics.* 74, 3: 381-393.

3 The Precision of Productivity Measures

John R. Baldwin and Tarek M. Harchaoui

3.1 Introduction

Statistics Canada is constantly improving its productivity measures so as to provide reliable information to the public. Nevertheless, uncertainty is clearly present in any statistical exercise. For the purposes of exposition, point estimates of productivity normally are the focus of attention. But the statistical process can rarely say with 100% certainty that statistics like productivity growth (or the unemployment rate) take on a particular value. Rather, point estimates need to be supplemented with confidence intervals within which the real values can be said to lie. Users require information on the size of these intervals if they are to make informed judgements on the use of the statistical product.

In order to fulfill this requirement, this chapter has three related goals. The first is to identify the size of the bounds that should be placed around the point estimates of productivity growth. The second is to evaluate the extent to which these bounds affect the use of productivity measures. The third is to draw implications about how these bounds affect cross-country comparisons of productivity performance.

Productivity measures are derived from data on the rates of growth of outputs and inputs. All the data that are used in producing estimates of productivity growth are subject to uncertainty—what we shall refer to as 'measurement error', which may be due to uncertainties resulting from the use of statistical sampling, inappropriate measurement techniques or data—capture problems.

Sampling may affect estimates of output and inputs used by the productivity program. These estimates are derived from surveys that use a complex stratified random sample taken from the whole population of households and corporations.[1] As such, these estimates are subject to sampling error that can be estimated.

Non-sampling errors from a number of sources may also affect these estimates. For instance, respondents to the survey may not have fully understood the questionnaire; there may have been data capture problems; or the use of imputation methods may have introduced additional uncertainty.

Various methods are used to reduce errors of these types in surveys. For example, Statistics Canada attempts to minimize respondent confusion with extensive pilot tests of surveys. Methodological advances are constantly being made in imputation techniques. Quality control techniques are used to monitor data capture. Nevertheless, it must be recognized that most data are subject to error and should be used with a clear understanding of the sources and extent of measurement error.

Statistics Canada provides data users with information on the nature of the errors and, where possible, quantitative indicators on the quality of the data. In the case of surveys like the Labour Force Survey (LFS), for example, measures of the coefficient of variation (CV) are available. A CV—the ratio of the standard error of the estimate to the mean—can be used to provide a quick measure of the interval within which the true but unobserved estimate of the mean falls.

Quantitative indicators of uncertainty, such as those available from the LFS do not extend to all the primary sources of data that are used by the productivity program. In fact, many of the data series originating from the National Accounts and elsewhere do not have CVs attached to them—yet they are all subject to a certain amount of imprecision.

[1] For example, Labour Force Survey for labour, Capital Expenditures Survey for investment, and Annual Survey of Manufactures for shipments.

Some of the uncertainty inherent in these statistics may be due to non-sampling errors that arise in data processing, or in the techniques that are used to construct time series estimates. For instance, the capital stock data are compiled from an investment survey, and the CVs from this survey are available. However, the capital stock program transforms the investment data into capital stock data by aggregating current investments to provide estimates of capital stock in the economy. These data manipulation techniques tend to introduce additional types of imprecision into the capital stock estimates since they involve assumptions about the length of life of capital and how rapidly capital wears out (the shape of the depreciation function). In some situations, these assessments are based on observed data, whereas in others, assumptions are based on expert judgement.

The capital stock program is not the only area where data transformation introduces measurement errors. As outlined in Appendix 1, the productivity program also transforms several data series. For instance, the labour component of the program relies heavily on the LFS for employment data. However, supplementary data are also used in an effort to improve the accuracy of the labour estimates for certain industries. This requires a certain amount of assumption and data editing, which introduces additional imprecision into the final productivity estimates.

The productivity program also uses expert judgement to produce a coherent set of adjustments to the data that, in their raw form, are not ideal for estimating productivity measures. For example, adjustments are made to the LFS data to account for strike activity and holidays. Despite the care exercised in adjusting the data that are used to derive productivity measures, errors remain in the data series.

It is important to give data users some idea of the bounds that should be used around point estimates of productivity growth. Those who wish to use the productivity estimates to conduct international comparisons need to have an understanding of the precision of the productivity measures. For example, between 1961 and 1997 multifactor productivity growth in Canada and the United States was 1.2% and 1.0%, respectively. Are these differences meaningful in a statistical sense? Are they statistically significant? An estimate of the bounds that should be placed around the point estimates or the variance of the estimates is required before questions of this type can be answered.

3.2 Error evaluation

In this chapter, we evaluate the precision of productivity estimates in several ways:

- using classical estimation techniques to estimate confidence intervals;
- examining what happens to estimates when we change the methodology for one of the most important inputs (for example, capital stock);
- asking whether international comparisons that use imperfect measures of inputs are imprecise; and
- asking how revisions in data affect productivity estimates.

Each method produces different confidence intervals or boundaries that should be employed when using productivity point estimates. In each of the following sections, we indicate the boundaries that are applicable in different circumstances.

Confidence intervals

A confidence interval provides bounds within which we would normally expect the true value of the estimated statistic to lie. For example, 19 times out of 20, a 95% confidence interval for a productivity growth rate will cover the true growth rate.

In estimating classical confidence intervals for our productivity estimates, we will make use of parametric as opposed to non-parametric estimation techniques of multifactor productivity.

The standard non-parametric (or accounting) technique calculates productivity as the difference between the rate of growth of output and the weighted average of the growth of inputs. The weights are simply the shares of factor compensation, which are estimates of marginal revenue products of different inputs.

Table 3.1. Parametric multifactor productivity growth estimates of Canadian manufacturing industries, 1961-1995[1]

	Parametric	Parametric lower bound[2]	Parametric upper bound[2]
	average annual growth rate %		
Food and Beverages	0.31	0.26	0.36
Tobacco	0.61	0.46	0.76
Textile	1.36	1.15	1.57
Clothing	0.85	0.67	1.03
Wood and Lumber	0.79	0.59	0.99
Furniture and Fixture	0.51	0.40	0.62
Paper	0.13	0.10	0.16
Printing and Publishing	0.01	0.01	0.01
Chemical	1.13	0.96	1.30
Refineries	0.51	0.40	0.62
Rubber	1.09	0.83	1.35
Leather	0.63	0.52	0.74
Non-mineral	0.84	0.74	0.94
Primary Metal	0.52	0.39	0.65
Fabricated Metal	0.86	0.74	0.98
Machinery	1.33	1.15	1.51
Electrical and Electronic	1.36	1.10	1.62
Transportation Equipment	1.17	0.97	1.37
Total Manufacturing	0.78	0.64	0.92

Note: 1. Based on gross output.
Note: 2. 95% confidence intervals.
Source: Chapter 8 of this publication.

These estimates of the standard non-parametric technique are essentially equivalent to those that would be produced using a parametric technique and assuming a production function of a specific type, that there are constant returns to scale, perfect competition and full capacity. We use this technique, which also readily produces confidence intervals of estimated parameters, to examine the size of the bounds that must be applied to estimates of multifactor productivity. For our purposes, we use a cost function rather than a production function (see Chapter 8)[2] to construct confidence intervals for assessing the precision of productivity estimates.

The parametric multifactor productivity estimates and their confidence intervals are presented in Table 3.1 for the entire manufacturing sector and for individual industries. The 95% confidence interval for the parametric estimate of the manufacturing sector extends about 0.28 percentage points, from 0.64 to 0.92. Alternately, the confidence interval is 0.14 percentage points above and below the point estimate of 0.78.

The confidence intervals that should be applied to subsectors are slightly larger. They range up to 0.50 percentage points and average about 38% of the mean point estimate.

The effect of alternative assumptions of inputs

Estimation of capital stock

We can also provide bounds around the productivity estimates by investigating how the estimates change when alternative methodologies are used to construct the input or output series that are used to calculate productivity growth.

To illustrate this technique, we will examine alternative methods that can be used to measure capital stock, each of which is quite reasonable. This is not a case where one methodology is definitively better than another. Rather, no consensus has emerged among economists on the best method.

We provide a different set of bounds for productivity growth rates by estimating productivity with alternative assumptions of capital stock. This allows users to assess how alternative methodologies for estimating capital stock affect the point estimates of productivity growth. It is particularly useful in cross-country comparisons when different countries use different techniques to estimate capital stock.

Capital stock is calculated in both Canada and the United States by the perpetual inventory technique. The declining balance method cumulates annual estimates of investment over time into an estimate of the capital stock, as follows:

$$K_t = I_t + (1 - \delta) K_{t-1} \qquad (1)$$

where K_t is real net capital stock, I_t is real investment, δ is the depreciation rate, and t refers to the year.

By successive backward substitution for K_{t-1} in (1), we can relate K_t directly to the initial value for the capital stock, K_0. Hence, K_t becomes a weighted sum of all past levels of investment and the depreciated value of the initial real capital stock.

$$K_t = \sum_{i=0}^{t-1} (1 - \delta)^i I_{t-i} + (1 - \delta)^t K_0 \qquad (2)$$

[2] Chapter 8 shows the differences between the production and cost function approaches to measuring productivity and how they can be used to measure productivity performance.

Figure 3.1 Survival rates for investments

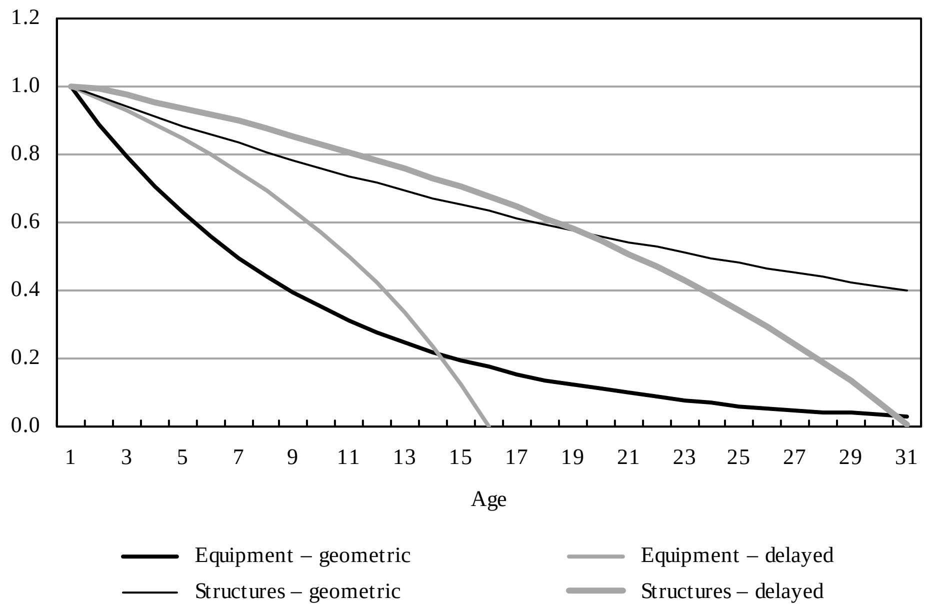
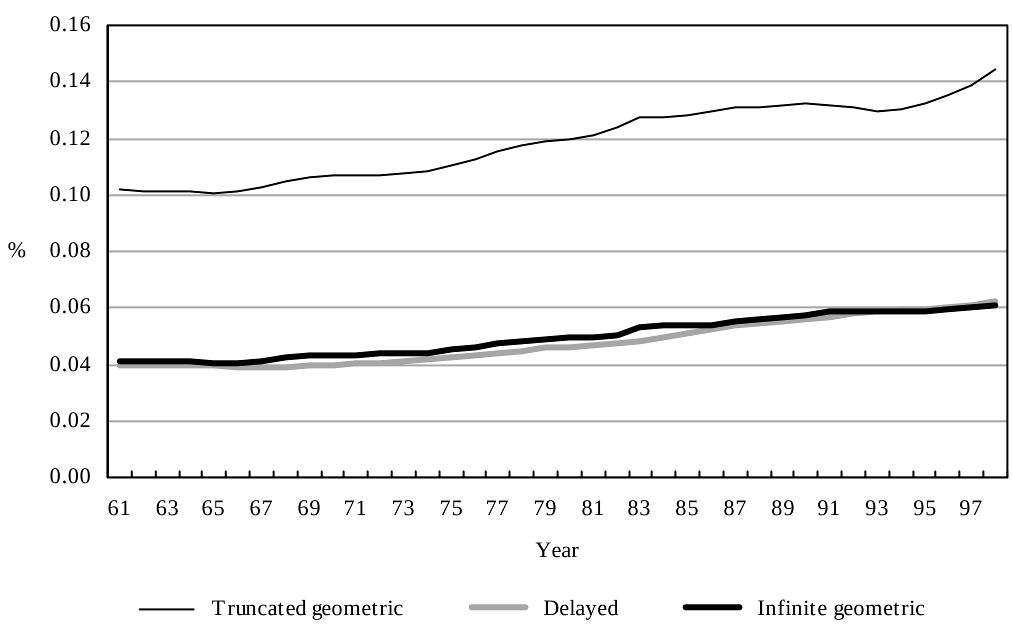


Figure 3.2 Depreciation rates of capital stock compared, business sector, 1961-1998



Measurement error may be introduced into the capital stock series through any of the three components of (2): the I_t series, K_0, and the depreciation profile that generates δ.

The error associated with the shape of the depreciation function arises because the choice of the shape is often subject to a certain degree of arbitrariness. For example, in the United States, the U.S. Bureau of Economic Analysis (BEA) and the U.S. Bureau of Labor Statistics (BLS) both produce estimates of capital stock, but they use different assumptions about the shape of the efficiency pattern of an asset.[3] The BEA assumes that the efficiency pattern follows a geometric distribution, whereas the BLS assumes a hyperbolic distribution.

The geometric distribution assumes that the rate of depreciation is a constant. The function that represents the value of $1 of original investment at age x is

$$F(x,L) = \delta(1-\delta)^{(x-1)} \tag{3}$$

In the case of the BEA, $\delta = \frac{R}{L}$, where R is an arbitrary constant and L is the life assumed. Thus,

$$F(x,L) = \frac{R}{L}\left(1-\frac{R}{L}\right)^{(x-1)} \tag{4}$$

The BEA uses the following approximation values for R: $R = 1.65$ for equipment and $R = 0.9$ for structures. L is taken from a table of lives that are obtained from a variety of sources (Fraumeni 1997, p. 9).

With a geometric efficiency pattern, the value of an investment declines at a constant rate δ, and the expected length of life yielded by the geometric distribution is $\frac{1}{\delta}$ or $\frac{L}{R}$. This means that the expected length of life of a structure whose L is taken as 30 years is 33 years. The expected length of life of equipment such as automobiles whose L is taken as 9 years is 5.5 years.

The delayed hyperbolic density function for an investment of life L is given by,

$$F(x,L) = \frac{[L-(x-1)]}{[L-\beta(x-1)]} - \frac{(L-x)}{(L-\beta x)} \tag{5}$$

where the BLS assumes $\beta = 0.75$ for structures and $\beta = 0.5$ for machinery and equipment.

Differences in the profile of the value of an investment of $1 for the two different assumptions about the efficiency and depreciation shapes are depicted in Figure 3.1. The geometric distribution for machinery and equipment assumes a life of 15 years, which along with the BEA assumption that $R = 1.65$ gives an annual rate of depreciation of 11%. For structures, we have chosen a length of life of 30 years, which along with the BEA assumption that $R = 0.95$ gives an annual rate of depreciation of 3%. The hyperbolic survival curve has been calculated with the assumption that $\beta = 0.75$ for structures and $\beta = 0.5$ for machinery and equipment.

The remaining or net value of an investment follows quite different paths for the geometric and the hyperbolic functional forms. Yet there are legitimate differences of opinion about which formula should be employed, as evidenced by the fact that the BEA uses one formula and the BLS uses another. Therefore, one yardstick that can be used to evaluate the precision of productivity measures is the difference in the productivity estimates that arise from the use of the two different capital stock estimates.

Sensitivity of productivity estimates to alternative assumptions on capital stock

To develop this yardstick, the productivity growth rate is calculated using alternative measures of the Fisher index of capital input[4]—where capital is calculated using the geometric and the delayed function outlined above. We also employ a variant of the geometric method, referred to here as the truncated geometric, that has long been produced by the Investment and Capital Stock Division of Statistics Canada (ICSD). In the case of this latter method, depreciation is assumed to follow a geometric pattern, but the function is truncated at the expected length of life of capital so that total depreciation at this point equals the original value of the asset (Statistics Canada 1994).

[3] An efficiency pattern is a pattern describing the productive services derived from an asset as it ages. The efficiency of a new asset is typically normalized to 1.0. As an asset declines in efficiency, its efficiency has a value of less than 1. There is a direct correspondence between efficiency patterns and depreciation patterns. Present and future declines in efficiency result in depreciation or declines in the value of an asset as it ages.

[4] See Appendix 1 for the method used to obtain a Fisher index of the growth in capital input.

Figure 3.3 Fisher index of capital inputs, business sector, 1961-1996

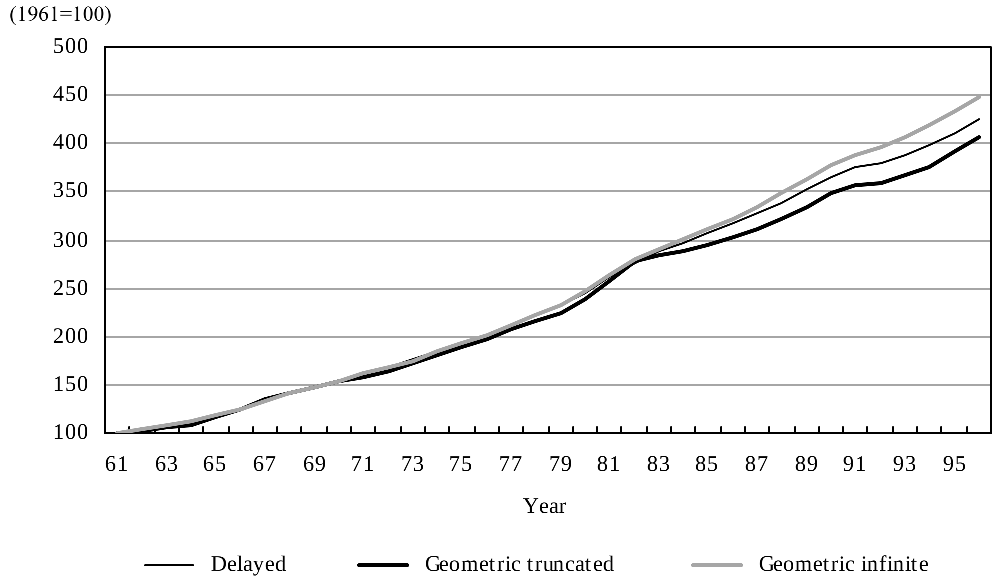


Figure 3.4 Capital inputs, business sector, average annual rates of growth, selected periods

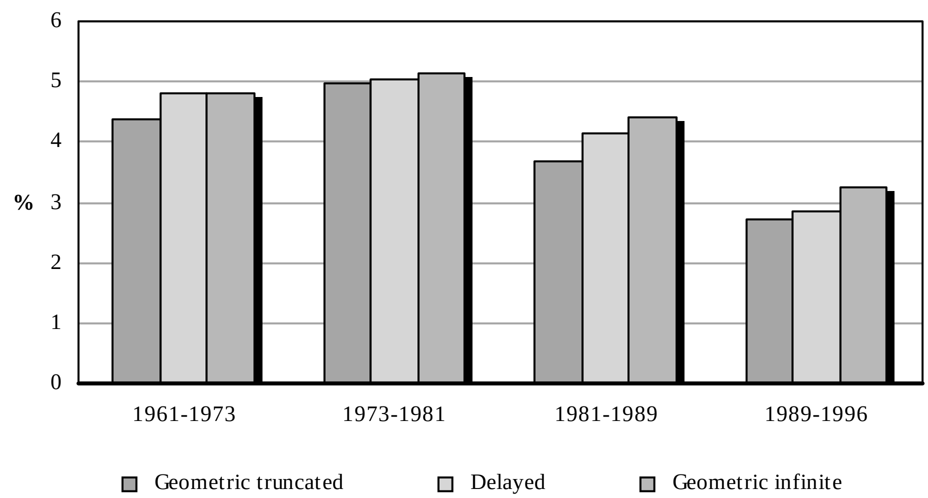
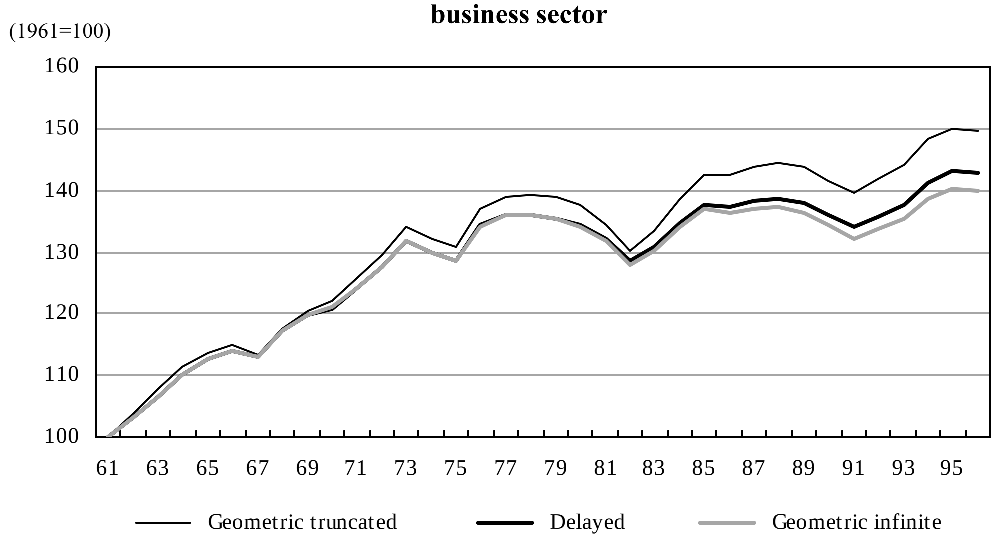


Figure 3.5 Cumulative growth in multifactor productivity[1] using different measures of capital stock, business sector



Note 1: Based on value-added.

These three different assumptions of the rate of depreciation of capital yield quite different estimates of the overall capital input. In Figure 3.2, we plot the rate of depreciation for each method over the period 1961-1998. This rate is obtained by dividing the value of the annual depreciation of capital stock by net capital stocks produced by ICSD. The truncated geometric yields the highest average depreciation rate (11.9%), followed by the geometric (5.0%) and the delayed hyperbolic functions (4.8%).

While the difference in depreciation rates between the truncated geometric method and the other two is large, it translates into much smaller differences in the rate of growth of capital input. Figure 3.3 displays the index of capital input for the period 1961-1996. Figure 3.4 shows its average annual growth rate for various subperiods. Over the entire period, the geometric grew the fastest at 4.4% annually, and the truncated geometric grew the least at 4.1% per year. The hyperbolic delayed growth rate fell between the other two, with an annualized growth rate of 4.2%.

The impact of these different capital input estimates on the productivity growth rate is provided in Figure 3.5. The technique that produced the slowest rate of growth of capital input had the highest growth rate in multifactor productivity (1.16%) over the period 1961-1996. The technique that yielded the highest rate of growth of capital input—the non-truncated infinite geometric—yielded an annual growth rate of 0.96%—a difference of 0.20 percentage points over the same period.

Clearly then, alternative assumptions about the form of the depreciation function that is used to construct capital stock have an impact on the estimate of multifactor productivity—one-fifth of a percentage point over a 36-year period. The average of the three growth rates is 1.05%, and the range (0.20 percentage point) divided by the average is 18%.

International comparisons and multifactor productivity estimates

In the first two examples, we have shown the type of bounds that should be placed around productivity estimates as a result of unavoidable sampling error or because of legitimate differences of opinion with regard to estimation techniques for inputs.

A third type of problem arises when incorrect data are used to estimate productivity. When an imperfect measure is used, the productivity estimates may be biased. To illustrate this problem, we turn to estimates of labour inputs.

Canada and the United States both utilize hours worked as a measure of labour input. However, international comparisons by the OECD use employment, measured by the number of jobs, primarily because they are interested in comparing countries, not all of which collect hours worked. The number of workers employed is commonly used in many studies that compare a large number of countries.

Hours worked is a better measure of the labour input into the production process when non-standard workweeks are important in an economy and if their importance has been changing over time. If increases in hours worked and employment over time are not the same, making use of employment rather than hours worked can provide misleading results about the rate of growth of labour inputs and, therefore, about the rate of productivity growth.

In Canada, hours worked and numbers employed (numbers of jobs) have not been increasing at the same rate. Figure 3.6 shows the cumulative rate of growth of both hours and employment over the period 1961-1996. Over this period, hours and employment grew at an average annual growth rate of 1.80% and 2.05%, respectively. The number of workers who work non-standard hours has increased over the last 20 years and, as a result, the true labour input (hours worked) has increased at a slower rate than employment.

We can evaluate how much of an effect this has on our estimates by recalculating the measure of multifactor productivity with employment rather than hours worked for the period 1961-1996 (Figure 3.7). Over this period, multifactor productivity using hours increased by 1.17% a year as compared with 1.0% if employment had been used in the estimates of labour input.

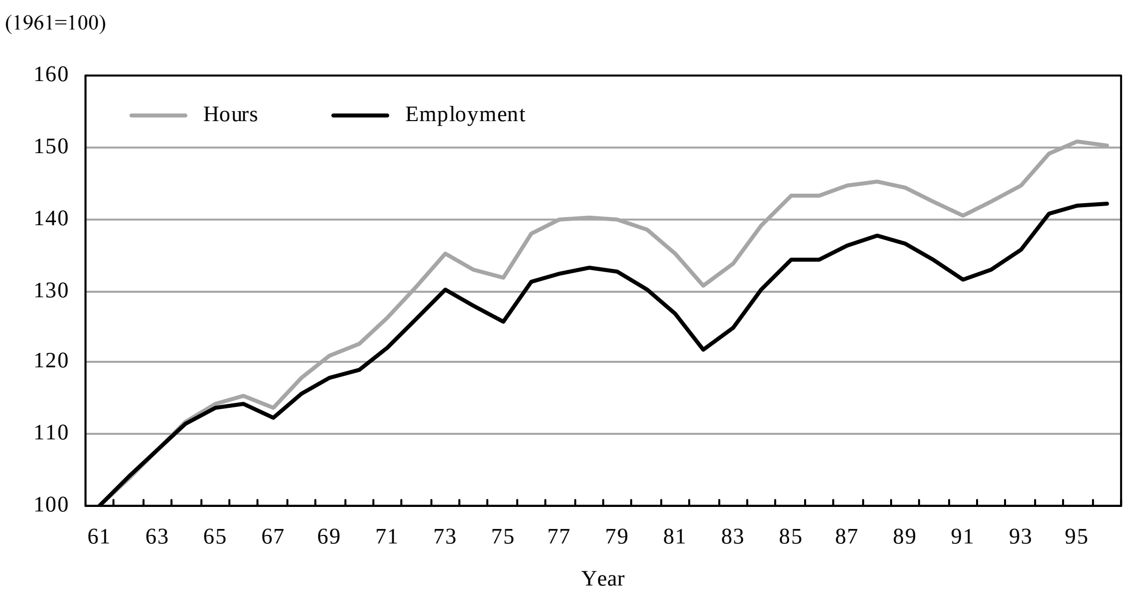
Thus, international comparisons made with data on employment will bias downwards the estimate of Canadian multifactor productivity growth. If these studies bias the estimates of all countries in the same direction, they may still provide a reasonably accurate ranking of Canada's relative position. But they will bias Canadian performance downward relative to that of other countries where rigid labour markets result in less flexibility for workers and cause hours worked and employment to increase at more or less the same rate.

Revisions and the accuracy of productivity estimates

Another method of evaluating the size of the bounds that should be placed around more recent productivity estimates is to examine the size of revisions that are made to the

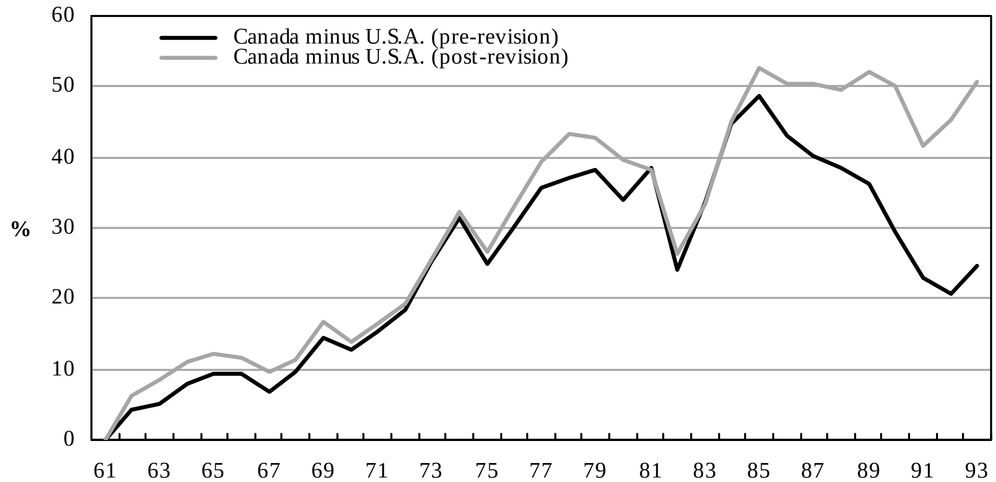
Figure 3.6 Fisher index of employment and hours

Figure 3.7 Cumulative growth in multifactor productivity estimates[1] under alternate labour input concepts, 1961-1996



Note 1: Based on value-added.

Figure 3.8 Cumulative differences in multifactor productivity growth[1] for Canada and the U.S., manufacturing, 1961-1993



Note 1: Based on value-added.

productivity estimates. Revisions to estimates are different from measurement errors due to sampling design problems or inappropriate measurement techniques described above.

Productivity measures are meant to provide estimates of technical progress. Trends in measures of technical progress only emerge over longer periods. Short-run or annual productivity estimates provide information that is less useful for this purpose.

Short-run annual estimates are less accurate measures of technical progress for two reasons. First, they are affected by short-run changes in capacity utilization that sometimes mean short-run changes hide long-run trends. Second, the most current annual measures are less accurate because they are based on preliminary data that are subject to revision. The size of the revisions that have occurred in the past serve as guides to the size of the confidence intervals that should be placed around preliminary point estimates of productivity growth.

For example, multifactor productivity measures in the short run are influenced by the fact that capacity utilization changes over the cycle. In recessions, installed capacity is not used to its fullest and estimates of capital services that do not take this fact into account will overstate the amount of capital being used. While there are statistical methods that can make corrections for this problem, their robustness and accuracy have not been fully established. As a result, short-run multifactor productivity estimates probably incorporate more of these short-run capacity fluctuations than is ideal.

This problem can be overcome only if long-run averages of productivity growth that cover an entire business cycle are taken. However, many users of productivity data cannot wait until an entire business cycle is completed. They need estimates of productivity annually. For that reason, Statistics Canada produces annual estimates throughout the business cycle, but it is only realistic to recognize that they are subject to revisions because of the addition of new information on components of GDP and to changes arising from periodic rebasing that takes into account changes in the structure of the economy (Jackson 1996).

The modifications that were made in 1998 to the Canadian and U.S. multifactor productivity estimates in the manufacturing sector illustrate the effect of revisions on productivity estimates.

Prior to the most recent historical revisions of the National Accounts Statistics Canada reported that the cumulative multifactor productivity growth in the manufacturing sector was 4.4% for the period 1987-1996. After the revision, the cumulative increase in productivity rose to 9.1%, in effect doubling the estimate of productivity growth since the last rebasing year (1986). It had less of an effect on the long-run rate of growth between 1961 and 1996, which increased from an annual average of 2.1% before the revision to 2.3% afterwards. This was an increase of about 8% in the rate of growth.

Changes as a result of revisions are not unique to Statistics Canada. In 1999, the BLS produced productivity estimates for the U.S. manufacturing sector that were not only benchmarked to the 1992 input-output tables but also reflected the revisions to the capital stock estimates made by the BEA (U.S. Bureau of Labor Statistics 1999, pp. 8-10). This revision reduced the U.S. manufacturing productivity estimates substantially, from a cumulative index of 151.2 to 139.9 in 1993, taken to a base of 1961=100. This is equivalent to an annual reduction from 1.30% to 1.06% over the same period, or a reduction of 0.245 percentage points. Over the period 1985 to 1993, the revision reduced annual growth from 1.04% to 0.78%, or 0.26 percentage points.

If we add the upward revision of about 0.15 percentage points in the Canadian estimates over the early 1990s to the downward revision of about 0.26 percentage points in U.S. estimates, we have a range of about 0.41 percentage points that we should apply before we treat short-run differences between Canada and the United States as being meaningful.

Revisions such as those described can dramatically affect cross-country comparisons. In Figure 3.8, we report the difference in the cumulative growth rates of Canada and the United States for the manufacturing sector between 1961 and 1993 before and after the revisions. Each series is the difference between the cumulative growth index based to 1961=100 for Canada and the United States. For example, in 1993 the unrevised cumulative index was 176 for Canada and 151 for the United States—a difference of 25 points.

Revisions made by both countries to their national accounts affect the nature of intercountry differences. The 1999 revisions substantially changed the cumulative difference of productivity growth as of 1993—doubling it from approximately 25 to 50 percentage points. More importantly, an entirely different picture of the relative performance of the two countries emerged in the early 1990s. Before the revisions, Canada appeared to have fallen relative to the United States. After the revisions, the two countries moved more or less in pace with one another.

Incorporating more current estimates of the structure of the economy into the productivity measures can therefore lead to large revisions in short-run productivity estimates. Users of productivity estimates that cover the very recent past should be aware that revisions can have a substantial impact on short-run productivity estimates.

3.3 Conclusion

Productivity growth is measured as a residual. It is the growth of output that we cannot explain by input growth. It is what we do not know about the growth process. When the estimates of productivity growth that are produced by Statistics Canada are used for analysis, it should be remembered that there is a confidence interval that should be drawn around these estimates when drawing inferences about the true rate of productivity growth.

Like unemployment estimates, productivity estimates are subject to measurement error. However, the unemployment estimates, which are derived from stratified random samples of populations, can make use of classical statistical sampling theory to generate estimates of confidence limits. It is more difficult to specify the size of these limits for productivity estimates because of the way in which the productivity statistics are generated.

In this chapter, we have suggested several approaches that can be used to gauge the intervals that should be attached to productivity estimates.

First, using classical statistical techniques and the assumption that there is no error in the estimates of inputs yields a confidence interval of around 0.3 percentage points. Second, changes in assumptions about the way in which capital estimates are calculated yield an estimate of the interval of between 0.2 and 0.3 percentage points. This suggests that the minimum confidence interval around the multifactor productivity estimates should be 0.3 percentage points. Since these two errors may be partially additive, the confidence interval that should be applied to the Canadian estimates is even larger than 0.3 percentage points.

These two estimates are useful when we come to setting the bounds around the productivity point estimates that Statistics Canada produces—when we try to compare differences in productivity growth rates across decades or across countries. This can be illustrated with a concrete example. In 1999, Statistics Canada reported that the annual multifactor productivity growth in Canada over the period 1961 to 1997 was 1.2%, slightly greater than the U.S. rate of 1% over the same period. On the basis of these data the productivity growth rates in the two countries were described as indistinguishable (Wells, Baldwin and Maynard 1999). The reason for this conclusion, despite differences in the point estimates of productivity growth in the two countries, is that the difference between the growth rates in the two countries is within the margin of error that either of the techniques discussed above produces.

The size of the confidence interval that should be applied to the productivity estimates will vary in other situations. If we are trying to assess what the true productivity growth in Canada was in a decade where the estimate was, say 1.2%, then the type of bound outlined above (at least 0.3 percentage points) should be used.

But if we want to argue that recent preliminary estimates for this decade fall below the estimates for the last decade, then we should be aware that past revisions in Canada have changed the productivity growth rates by approximately 0.2 percentage points and therefore our confidence intervals should probably be even larger than 0.3 percentage points—perhaps as large as 0.5 percentage points.

If we want to argue that Canada's productivity growth rate was different from that of another country, then we probably have to expand the confidence interval used for this purpose, if the methodologies in the two countries are different or if productivity statistics are calculated with incorrect labour or capital data. This is the case for international comparisons like those of the OECD, which use imperfect labour input measures.

All of this means that conclusions about changes in productivity trends and differences across countries need to be made cautiously. Productivity measures are first differences of first differences—that is, they are calculated as the difference between changes in output and changes in inputs. Errors in one component can have a magnifying effect on changes in the overall productivity measure. For example, in recent months the rate of output growth in the United States has been revised upward from 3.1% to 3.5% and productivity growth has been revised from 1.2% to 1.6% (Seskin 1999). A 13% error in estimated output growth translates into a 33% error in the estimate of productivity growth. Productivity measures therefore inherently have less precision than the output and input components that enter into the formula and that are used to calculate productivity growth.

References

Fraumeni, B.M. 1997. "The Measurement of Depreciation in the U.S. National Income and Product Accounts." *Survey of Current Business*. July: 7-23.

Jackson, C. 1996. "The Effect of Rebasing on GDP." *National Economic and Financial Accounts, Quarterly Estimates.* Statistics Canada Catalogue no. 13-001-XPB. Second quarter. Ottawa.

Organisation for Economic Co-operation and Development (OECD). 1999. *International Sectoral Database 98, User's Guide*. Statistics Directorate. Paris: OECD.

Seskin, E. 1999. "Improved Estimates of the NIPA's for 1959-98: Results of the Comprehensive Revision." *Survey of Current Business.* 79. December: 15-39.

Statistics Canada. 1994. *Fixed Capital Flows and Stocks, 1961-1994: Historical.* Catalogue no. 13-568. Ottawa: Minister responsible for Statistics Canada.

U.S. Bureau of Labor Statistics. 1999. *Multifactor Productivity Trends*. February 11. Washington, D.C.: U.S. Department of Labor.

Wells, S., J.R. Baldwin and J.P. Maynard. 1999. "Productivity Growth in Canada and the U.S." *Canadian Economic Observer.* September. Statistics Canada Catalogue no. 11-010-XPB. Ottawa.

4 Productivity Growth in Canada and the United States

John R. Baldwin, Tarek M. Harchaoui and Jean-Pierre Maynard

4.1 Introduction

Productivity statistics are frequently used to compare performance across countries. Interest in productivity growth often focuses not just on how well Canada is doing, but whether it is gaining or falling behind its major trading partners. Intercountry differences like these are useful in understanding the reasons for differences in the standard of living, the competitiveness of national industries, and the causes of trends in the exchange rate. In this chapter, we examine differences in the course of productivity growth between Canada and the United States.

We do so in three different sections. The first section looks at long-run trends in productivity growth in the business sectors of the two countries, over the period 1961-1999. The second section does the same for the manufacturing sector. The first two sections focus on long-run trends in the two economies because short-run data are quite volatile. In the third section of this chapter, however, we examine short-run growth in labour productivity because, since 1995, the growth in the United States has attracted attention.

Before proceeding, it is important to warn readers of the inherent difficulties in cross-country comparisons. Cross-country comparisons of productivity are invariably imprecise because of differences in methodology employed in different countries. Output and inputs are not always measured in the same way. For example, labour can be measured as the number of jobs, the number of people employed or the number of hours worked. Capital input can be estimated using capital stock or the flow of capital services.[1] Differences in the measurement of output are illustrated by the differences in the treatment of software, between the United States and Canada. Under the latest U.S. methodology, expenditures on software are capitalized whereas under the Canadian conventions they are mainly expensed.

The U.S. Bureau of Labor Statistics provides measures of labour and multifactor productivity that are reasonably comparable to those of Canada. While not exactly the same, they are closer than the estimates available for many other countries and, therefore, provide us with a foundation for a Canada-United States comparison. Nevertheless, it must be remembered that the methodology is not exactly the same and therefore the comparisons are not perfect. We point out differences where they are most relevant.

4.2 Business sector productivity growth, 1961-1999

Comparisons between Canada and United States that are based on labour productivity growth are perhaps the most straightforward. Both Statistics Canada and the U.S. Bureau of Labor Statistics report a labour productivity measure for the business sector.[2] Both countries use GDP as a measure of output, though the United States adopts a measure based on GDP at market prices, whereas Canada uses GDP at basic prices.[3] Both countries use hours worked as a measure of labour input.

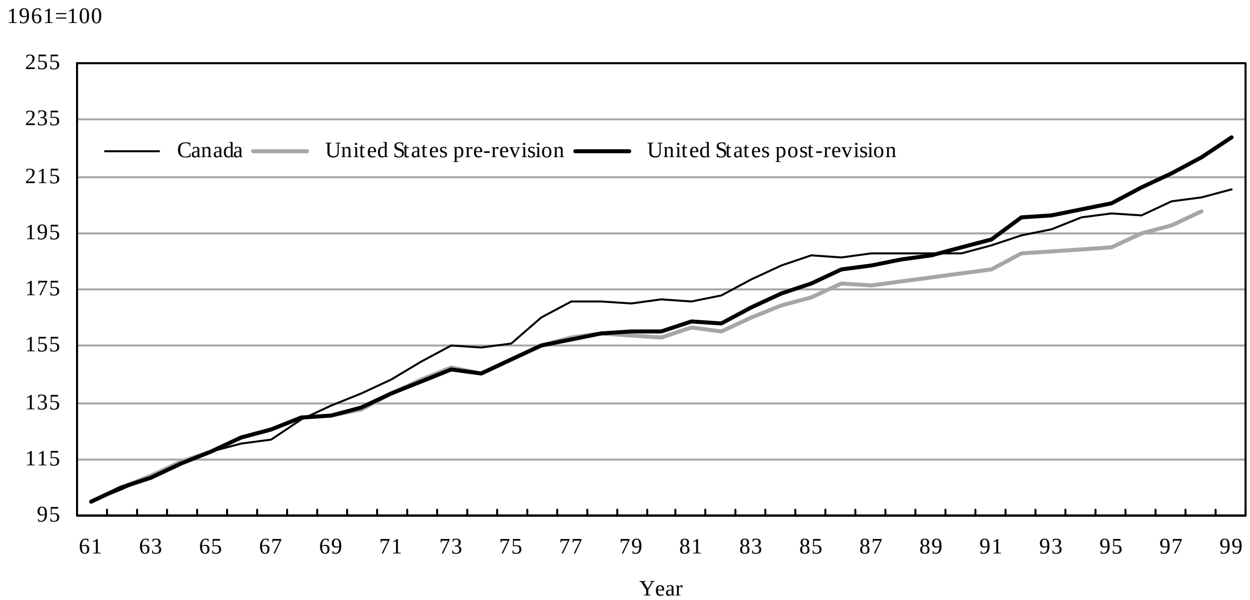
It must nevertheless be recognized that there are some differences in methodology. In particular, the U.S. concept of GDP has recently been revised. These revisions involve the capitalization of software expenditures, and making

[1] The flow of capital services is the flow of services yielded by the capital stock.

[2] In Canada, this calculation excludes a large portion of the health and education sectors. In the United States, the business sector excludes the public education sector.

[3] See Appendix 1 for Canadian methodology.

Figure 4.1 Cumulative growth in business sector labour productivity, Canada and United States



better use of spliced price series to take into account qualitative changes in the consumer price index. Canada uses a similar concept of GDP, except for the former adjustment.

The changes in the U.S. methodology have increased their rate of labour productivity growth by as much as 33%. This new methodology reduces the direct comparability of the two official labour productivity series.

We deal with this problem by reporting two measures of labour productivity for the United States (Figure 4.1). The first utilizes the 1999 estimates that are more comparable with Canadian estimates of GDP.[4] The second uses the revised estimates of the U.S. labour productivity series that was released in 2000, and are less comparable with Canadian GDP.[5]

Year-to-year growth rates are often severely affected by economic cycles and do not provide a very good measure of long-term movements in relative efficiency. For that reason, we plot the cumulative gain in productivity for Canada and the United States since 1961.

A comparison of the growth in labour productivity in the business sectors of Canada and the United States using the cumulative pre-revision series shows that Canada was consistently ahead of the United States from the late 1960s to the present. Although not comparable with their Canadian counterpart, the revised U.S. series indicates the emergence of an increasing gap in favour of the United States beginning in the early 1990s.

Trends in multifactor productivity growth are more difficult to compare than labour productivity because of larger methodological differences used in constructing these measures.[6]

It should be noted that at the time of this writing, the United States had not revised its multifactor productivity estimates to reflect the new GDP methodology, and therefore we report only one estimate of multifactor productivity—an estimate based on GDP that does not capitalize software.

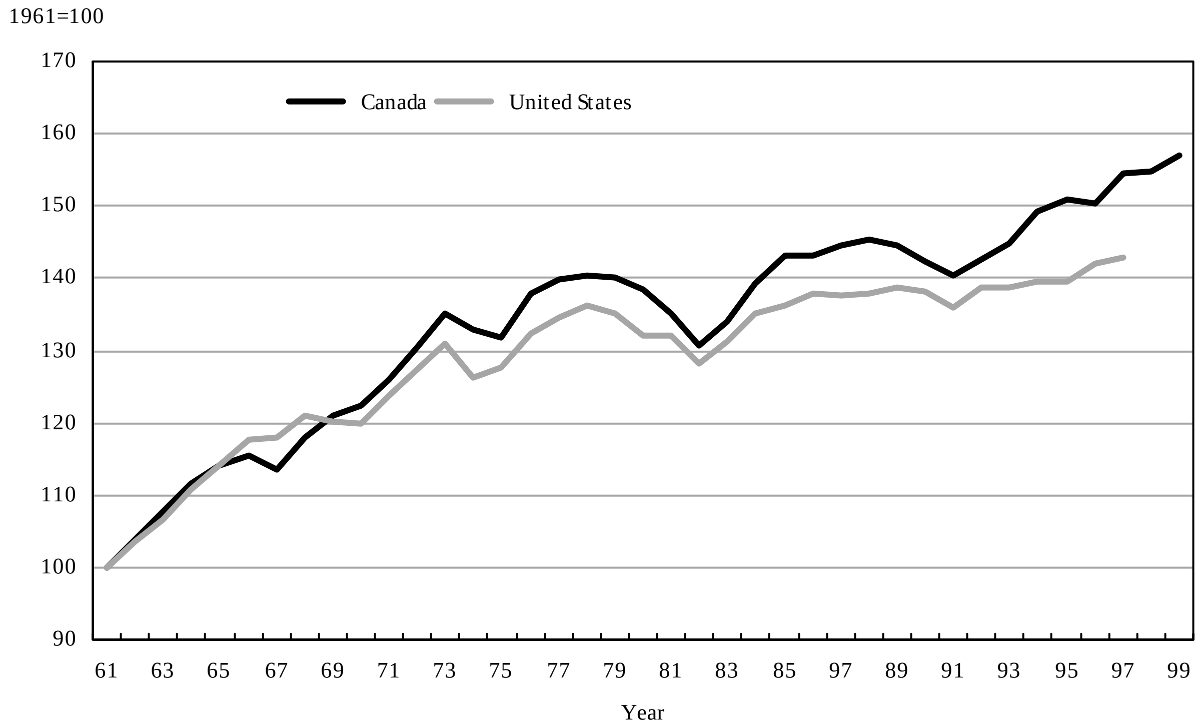
A comparison of cumulative multifactor productivity growth for the business sector in both countries shows

[4] U.S. Bureau of Labor Statistics, NEWS, August 27, 1999.

[5] U.S. Bureau of Labor Statistics, NEWS, March 7, 2000.

[6] First, the United States makes corrections for the quality of labour in its measures of growth for the economy as a whole that are different from the corrections made in Canada. Second, the methodology underlying the construction of the capital input in both countries is slightly different. The rates of depreciation implicit in the U.S. approach are lower than those derived in Canada. On the other hand, the United States includes land and inventories in its estimate of capital while Canada does not. In addition, Canada assumes that the flow of capital services from a dollar of capital of stock is the same across asset types while the United States does not (see Appendix 1 in this publication). Research is under way to examine the effect of incorporating similar assumptions in the Canadian estimates.

Figure 4.2 Cumulative growth in business sector multifactor productivity, Canada and United States[1]



Note: 1. Based on value added.

Canada growing at a faster rate than the United States (Figure 4.2).[7] Until the early 1980s, there is little difference between the two countries. Since that time, however, Canada has moved *slightly* ahead of the United States. Nevertheless, these differences are not large—less than 0.2% per year—and well within the margin of error that is associated with the estimation of productivity indices (see Chapter 3). We would conclude that, based on this data, there is no evidence of significant differences in overall multifactor productivity growth in the business sectors of the two countries.

It is noteworthy that there are substantial differences in the cyclical effects in the measured rates of multifactor productivity growth. The rates of growth for both Canada and the United States show the effects of the recession in the early 1980s. The recession of the early 1990s had a marginal effect on the rate of productivity growth in the United States, whereas Canada experienced a more pronounced productivity slowdown during this period.

These results imply that Canada-United States comparisons of productivity performance can be quite sensitive to the choice of endpoints. Whether choosing years like 1988 (a peak year) and measuring for short periods through the recession in the early 1990s (a trough year), or doing the same in the early 1980s, short run measurements will give a more pessimistic view of Canada's performance relative to the United States, as compared with longer run comparisons.

In order to investigate the importance of differences in methodology on Canada-United States comparisons, we recalculated the multifactor productivity estimates for Canada and the United States to make them even more comparable. First, we removed the correction for changes in worker quality that is normally included in U.S. estimates. We did the same for Canada.[8] We then recalculated the rate of growth of capital stock for Canada by using the delayed (or hyperbolic) depreciation function that is employed by the BLS in the United States. Next, we

[7] Multifactor productivity estimates are based on the official Statistics Canada series and the official series from the U.S. Bureau of Labor Statistics.

[8] We did so by calculating the growth rate of the sum of all hours worked across industries as opposed to a weighted sum where the weights are the share of total payroll of each industry (see Appendix 1).

Figure 4.3a Business sector multifactor productivity growth[1], Canada and United States, 1961-1997

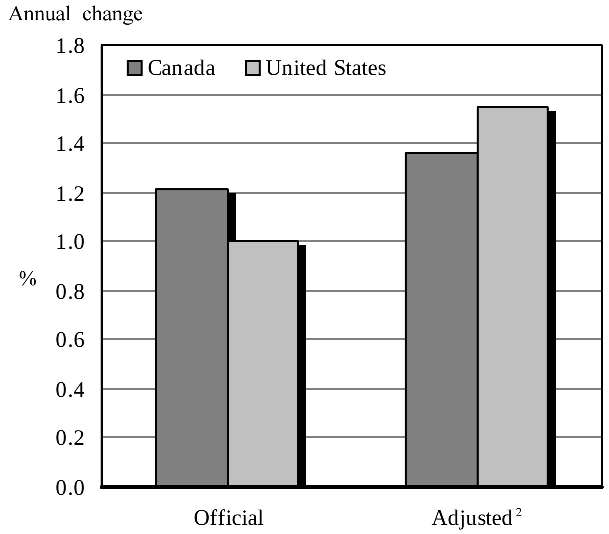
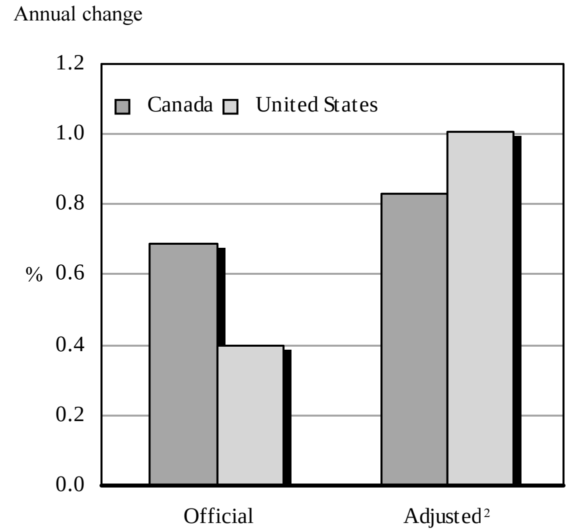


Figure 4.3b Business sector multifactor productivity growth[1], Canada and United States, 1988-1997



Notes: 1. Based on value added.
2. For both countries, labour input and capital input are measured, respectively, as the sum of hours and the sum of capital stock net of hyperbolic depreciation (machinery and equipment and structures).

calculated the rate of capital growth for the United States, using the sum of productive capital stock (not the sum of capital services), and using only the categories used in Canada—namely, machinery and equipment, and structures. We use the estimates of GDP growth excluding software investments for the United States. Finally, we compared the Canadian rates of productivity growth with that of the United States, using the official estimates of the two countries and these more comparable estimates (adjusted). This is done in Figure 4.3a for the period 1961-1997, and in Figure 4.3b for period 1988-1997.

Over the entire time period, the official estimates show Canadian performance exceeding that of the United States (1.2% and 1.0%, respectively). The differences are within the margin of error that must be ascribed to uncertainty (see Chapter 3). When the estimates are adjusted for comparability, Canada falls slightly behind the United States (1.4% and 1.6%, respectively). However, the differences between the two countries are still within the margin of error. Over the period 1988-1997 (Figure 4.3b), the same trend emerges. Canada and the United States follow essentially the same productivity growth path and the differences are still within the margin of error described in Chapter 3.

On balance, these data show substantial similarity in the growth of productivity between the Canadian and the U.S. economies over the last 40 years. Several factors contribute to this: the proximity of the two economies, the large amount of foreign investment that leads to technology transfer, similarities in the available technologies, and the close trading relationship that exists between Canada and the United States.

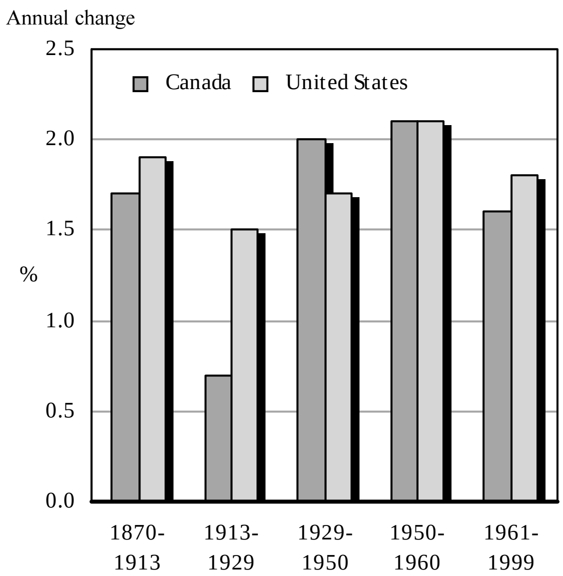
Is there something special about the period since 1960? Did we perform more or less well in previous periods when the two economies were less integrated, when Canada's trade was more closely oriented with England and the British Commonwealth, when the economy was more heavily reliant on the extraction of natural resources?

To answer this, we examine historical trends in labour productivity[9] dating back to the years just after Confederation (Figure 4.4).[10] It is clear that similarities in labour productivity growth have been with us since that time.

[9] For purposes of historical comparability, labour productivity is defined here using total GDP divided by employment and not business sector GDP divided by hours worked as was done in Figure 4.1. We utilize the 1999 estimates of U.S. GDP that are closer to the Canadian methodology.

[10] For this graph, the Canada-United States comparisons are taken from the U.S. Department of Commerce (1975), which based its comparisons on Angus Maddison's work *Economic Growth in the West* done for the Twentieth Century Fund. The comparisons prior to 1960 use GNP for the entire economy. Those after 1960 use GDP for the business sector.

Figure 4.4 Output per employee



Except for the period after World War I, Canada has consistently tracked the labour productivity performance of the United States. Despite our distinctiveness in terms of trade orientation with Britain before World War II, our greater reliance on natural resources, and our adoption of a more comprehensive social safety net, our productivity growth has increased by about the same amount as that of the United States in just about every major phase of our industrial history. While a slowdown has occurred in the period after OPEC, our slowdown is the same as that of the United States.

4.3 Productivity trends in manufacturing, 1961-1999

The manufacturing sector tends to get special attention in intercountry productivity comparisons, partly because of its importance in trade relations with the United States, and partly because of the impact of the Canadian-U.S. dollar exchange rate on that sector.

As mentioned earlier, the United States uses GDP at market prices, and a perpetual inventory type capital stock calculated net of depreciation that places different weights on different types of capital stock via the use of a rental rate of capital. Unlike its estimates for the business sector, however, the United States adopts hours worked with no adjustments for labour quality at the sector level.

The Canadian data use GDP at basic prices, a perpetual inventory type capital stock technique that weights equally all assets and hours worked. Improvements in labour quality are included in the Canadian hours worked estimates via the industry weighting scheme that is used for aggregation purposes.

Estimates of multifactor productivity growth in the manufacturing sector of Canada and the United States are presented in Figure 4.5. Productivity growth in the United States experienced robust growth in the early 1970s, followed by a period of slower growth in the late 1970s. In contrast, productivity growth in Canada experienced relatively faster growth in the earlier period followed by slower growth. The performance of the U.S. manufacturing sector jumped ahead of Canada during the growth phase of the 1990s recovery, when productivity growth of the United States slightly exceeded that of Canada.

There is substantial two-way trade that ties the economies of Canada and the United States together. Over 60% of Canadian manufacturing shipments is accounted for by foreign-owned companies. In these circumstances, it is likely that gains in knowledge that lead to increases in productivity will be quite similar, though not identical.

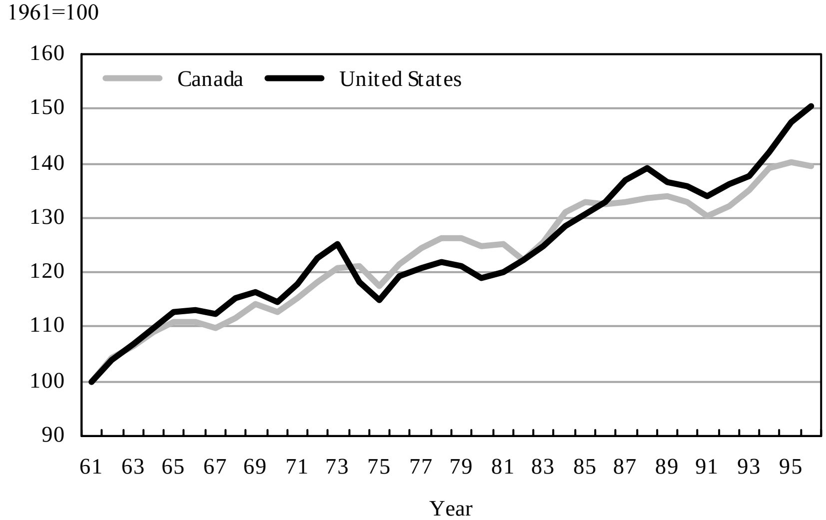
One way to test this is to ask how the experience of different industries is related over time. To accomplish this, we developed multifactor productivity measures for a set of 17 Canadian manufacturing industries that corresponded to comparable published data for 17 U.S. industries at the two-digit SIC level.

In order to investigate the relationship between the two countries, we correlated the productivity performance of these seventeen industries over the period 1961-1996. Over the entire time period, the correlation between the growth of Canadian and U.S. industries was close to 0.7, indicating that on an industry-by-industry basis, there is evidence to show that the same forces have been at work in both Canada and the United States.

Despite these similarities, it is still useful to examine the growth rates in Canada and the United States during the pre- and post-1992 periods so as to confirm whether there is any indication of general similarities across most industries or whether there are any major industry-specific differences (Figure 4.6a and 4.6b).

Before 1992, there is an obvious similarity in the performance of the manufacturing industries of both countries (Figure 4.6a). In general, the industries with the highest Canadian productivity growth rates also have the highest productivity growth rates in the United States. However, there are some noteworthy differences. In the United States, the machinery and electronics industries grew at almost twice the rate of every other industry, and considerably

Figure 4.5 Cumulative growth in manufacturing sector multifactor productivity[1], Canada and United States, 1961-1996



Note: 1. Based on gross output net of intra-industry sales.

more than its Canadian counterpart. In about half of the industries, productivity growth in Canada is higher than the United States.

If we turn to the post-1992 period and perform the same comparison (Figure 4.6b), it is apparent once again that there is a large difference in two areas—machinery and equipment, and electrical and electronic products. It is noteworthy, however, that U.S. productivity growth in the latter industry dominates that of all other industries in the United States.

The electrical and electronic products industries in the United States contain the bulk of the computer industry. But it should be noted that these are the two sectors where hedonic price indices have been used to account for quality improvements.

The number of industries in which Canada is leading dropped significantly (from 10 in the pre-1992 period to 5 in the post-1992 period), but the performance of Canada remains close to the United States in the largest traditional industries such as paper and allied products, chemicals, and primary metals.

4.4 Performance of the business sector, 1995-1999

The previous sections have examined the differences in long-run productivity trends in Canada and the United States. We focus on long-run trends because short-run data are less accurate and subject to more error because of revisions (see Chapter 3). Nevertheless, in recent years, a marked difference has emerged in U.S. productivity growth that must be noted.

Since 1995, U.S. growth in labour productivity has moved well above its long-run post-1973 average of 1.5%. In the four years after 1995, the U.S. economy has experienced record shattering labour productivity growth rates of 2.8%, 1.9%, 2.9%, and 3.2%, respectively (Figure 4.7).

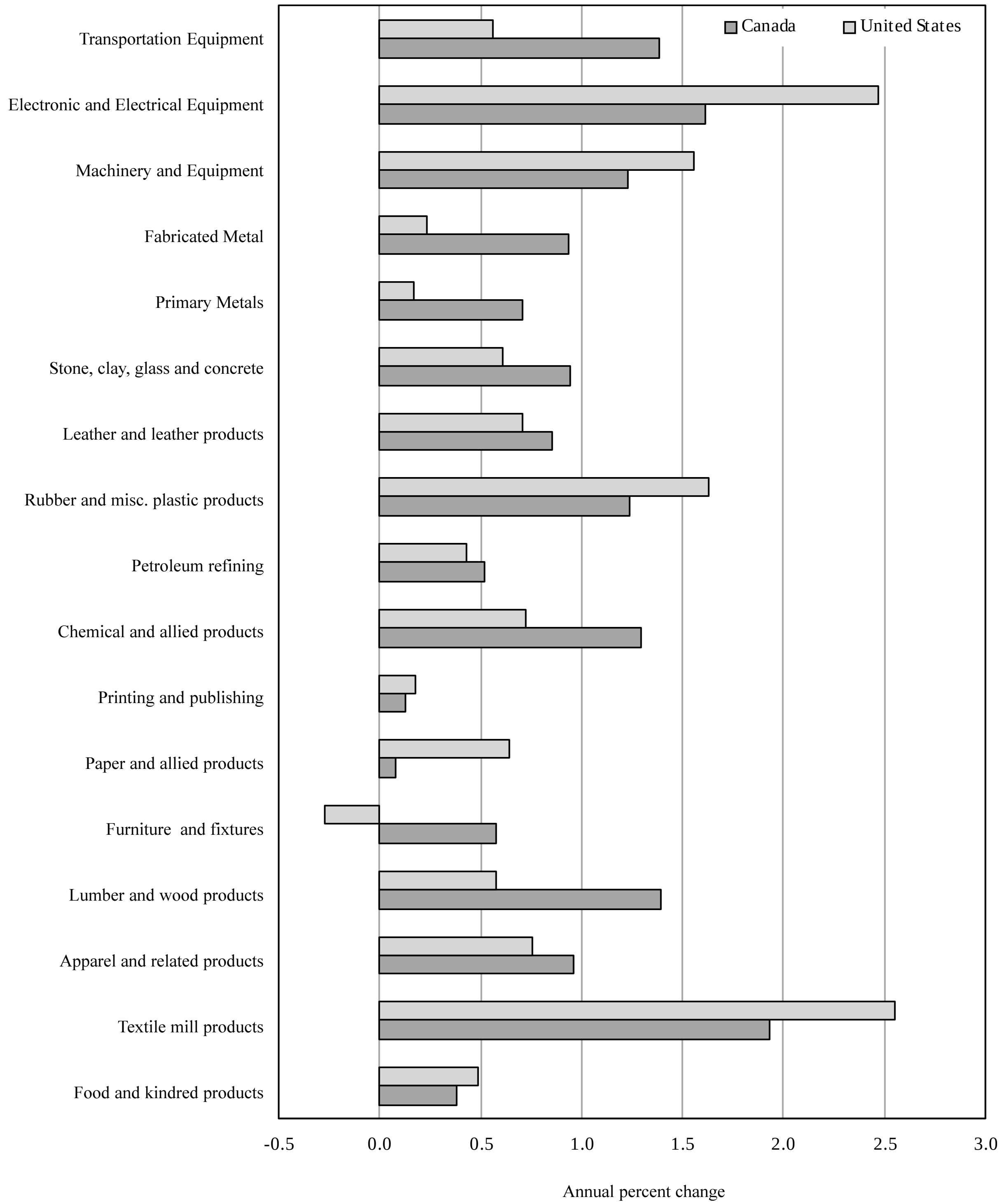
Comparisons of labour productivity between Canada and United States over the most recent period have been affected by recent changes in the definitions and in the statistical methodologies that were incorporated into the United States National Accounts with the completion of their 1999 historical revisions.

These changes have increased the annual rate of U.S. GDP growth from 2.8% to 3.3% annually, between 1978 and 1998. In turn, this has increased the U.S. estimates of labour productivity over the same period from 1.2% to 1.6% annually. The 18% revision in U.S. GDP growth rates translates into a 33% increase in productivity growth. Almost half of the increase arises from the inclusion of software investments.[11]

Both the old and the new estimates of U.S. business sector labour productivity growth are presented in Table 4.1. Prior to the U.S. revisions, Canada performed slightly better than the United States over the period 1961-1978 (3.2% versus 2.8% annually, respectively), and slightly worse than

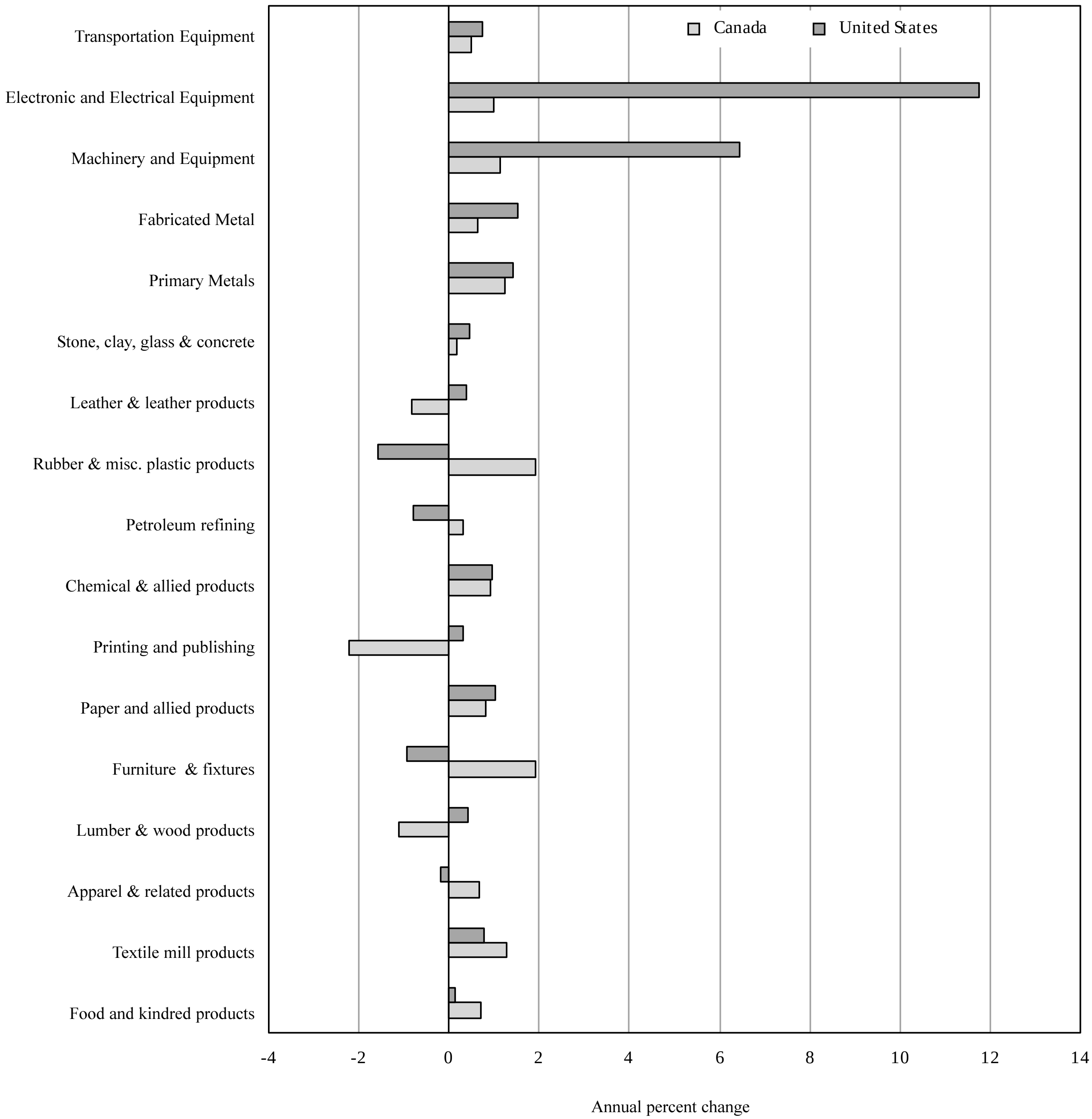
[11] Parker and Grimm (2000).

Figure 4.6a Manufacturing sector multifactor productivity growth[1], Canada and United States, 1961-1992



Note: 1. Based on gross output net of intra-industry sales.

Figure 4.6b Manufacturing sector multifactor productivity growth[1], Canada and United States, 1992-1996



Note: 1. Based on gross output net of intra-industry sales.

Table 4.1 Comparison of business sector labour productivity growth, Canada and United States, 1961-1999			
	annual growth rates (%)		
	U.S previous	U. S. new	Canada
1961-1978	2.8	2.8	3.2
1978-1998	1.2	1.6	1.0
1978-1999	..	1.7	1.0
1996	2.7	2.8	-0.1
1997p	1.4	1.9	2.4
1998p	2.4	2.9	0.5
1999p	..	3.2	1.4

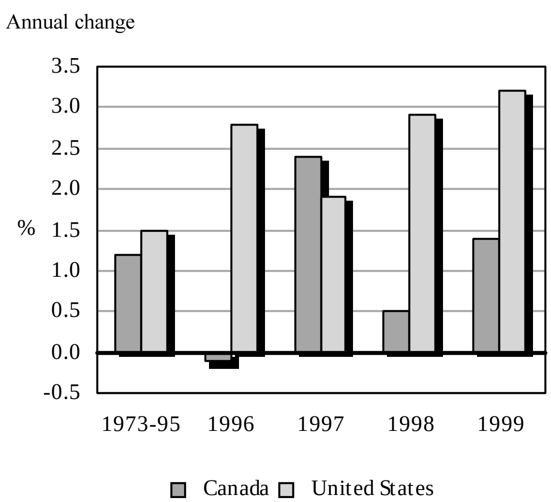
Note: .. Figures not available.
p Preliminary.

the United States over the period 1978-1998 (1.0% versus 1.2%, respectively).

After the revisions to the productivity estimates in the United States,[12] productivity growth in Canada is further behind that of the United States over the latter period.

Preliminary estimates of Canadian and U.S. productivity for recent years suggest a widening gap between the two countries. Though subject to revision, these estimates show that Canadian labour productivity over the last four years has grown at a cumulative rate of 4.2%, whereas the United States experienced a cumulative growth rate of 11.5%. Even before the U.S. historical revisions, U.S. labour productivity growth during these years was above Canadian growth and continues to be so by a considerable margin (Figure 4.7).

Figure 4.7 Business sector labour productivity growth in Canada and the United States— selected periods



4.5 Conclusion

Productivity growth in the economy is an important contributor to improvements in our standard of living. It is affected by small, incremental changes in a host of factors that occur on the plant floor. These include new production techniques, changes in plant size, changes in organization as well as other factors that are associated with new knowledge.

These changes are generally not cataclysmic. Even momentous changes involving new technologies take time to implement. These changes are relatively steady, when measured over long cycles. Since the First World War, the annual growth rates of labour productivity have averaged very close to 2% per year. They slow down after 1973— but the slowdown in Canada has been much the same as in the United States.

What is remarkable about the historical performance of productivity growth in the Canadian economy is its similarity to that of the United States. During different periods when we have experienced war and peace, a transition to a society that has a stronger safety net and other societal changes, the rate at which new knowledge has been incorporated into the production process has been relatively steady and about the same as the United States. Over almost 40 years since the 1960s, Canada has continued to move in step with the United States. This has occurred at the same time that trade has become more liberalized between the two countries. Moreover, the similarities in performance extend back over 100 years when measured over long periods.

[12] No corresponding revisions were made in Canada.

References

Parker, R. and B. Grimm. 2000. "Software and Real Output: Recent Developments at the Bureau of Economic Analysis." *Bureau of Economic Analysis.* U.S. Department of Commerce. April 7.

U.S. Bureau of Labor Statistics. 1998. "Multifactor Productivity Trends, 1997." *NEWS*. May 6.

———. 1999. "Productivity and Costs - Second Quarter 1999." *NEWS.* August 27.

———. 2000. "Productivity and Costs, Fourth Quarter 1999." *NEWS*. March 7.

U.S. Department of Commerce, Bureau of the Census. 1975. Washington: 20th Century Fund.

5 Heterogeneity in Labour Productivity Growth in Manufacturing: Differences Between Domestic and Foreign-controlled Establishments

John R. Baldwin and Naginder Dhaliwal

5.1 Introduction

Discussions of productivity usually focus on economy-wide aggregates. The course of these aggregate measures is determined by the performance of sub-populations. Since differences in labour productivity reflect differences in technology, capital intensity, size, and other firm-specific factors, it is important to look at how Canadian productivity performance differs across subgroups if we are to detect underlying weaknesses. In this chapter, we focus on differences in two major subgroups of the overall population—establishments that differ by size and by nationality of control.

An examination of productivity differences across size classes is important since job growth in the manufacturing sector has been predominantly concentrated in small establishments (Baldwin and Picot 1995). However, labour productivity is lower and falling in small establishments relative to large establishments (Baldwin 1998). The growth in the share of employment in small establishments, therefore, would have had the effect of slowing labour productivity growth in the manufacturing sector (Baldwin 1996).

An analysis of productivity differences by nationality is equally relevant since foreign-controlled firms are mostly large and capital intensive, and are often seen as the vehicle through which new technologies are incorporated most quickly into the economy. These firms account for about 55% of shipments in the manufacturing sector in 1993 and, therefore, have an important impact on both aggregate labour productivity and job growth.

5.2 The importance of foreign control

The policy regime that affects foreign investment in Canada has changed over the last 20 years in two ways. First, trade liberalization has seen tariffs gradually fall. The Kennedy round of General Agreement on Tariffs and Trade (GATT) tariff reductions was felt in the 1970s and the Tokyo round followed in the 1980s. These two multilateral rounds of tariff reductions were followed by bilateral tariff reductions between Canada and the United States in 1989 as a result of the Canada-U.S. Free Trade Agreement (FTA) and then the North American Free Trade Agreement of 1992 (NAFTA).

While tariff reductions lessened the barriers to the movement of goods, changes in the investment regulatory regime have reduced barriers to the movement of capital. Prior to 1983, the Foreign Investment Review Agency regulated foreign investment. In 1983, this was replaced with a new agency (Investment Canada), whose mandate was seen to be less restrictive in the sense of facilitating and soliciting foreign investment rather than controlling it. At the same time, foreign investment provisions of both FTA and NAFTA changed the thresholds required for review before the agency.

Liberalized trade and regulatory regimes might be expected to affect foreign direct investment in a number of ways. First, reductions in regulation decrease the cost and uncertainty involved with foreign investment and should be expected to increase investment. Second, tariff reductions allow firms greater flexibility in optimizing their production facilities. Whether this would result in foreign operations leaving Canada depends on whether the Canadian market can be better served from abroad or with production facilities in Canada once tariffs are decreased, and whether Canada has a comparative advantage in some areas that would lead production to be located here.

Traditional theories of foreign trade try to answer this question by focusing on the extent to which country-specific factors that determine the costs of business affect the pattern of international trade. The costs of business are determined by factor endowments, production processes, transportation costs, tax and regulatory regimes. These comparative advantage theories are not ideally suited to explain the creation of the multinational firm—an organization that has production facilities in different countries. In response, a theory of transnational firms has been developed to explain why firms internalize transactions across national boundaries rather than engage in arm's-length trade.

One strand of this literature focuses on the existence of assets that are difficult to trade—either because these knowledge-based assets lead to asymmetric information difficulties or problems in writing contracts, evaluating results and monitoring performance. These assets could involve proprietary production technology, unique marketing skills, trademarks, or brand names (Caves 1982). Because assets are assumed to be difficult to exchange efficiently via market mechanisms, firms are seen to set up shop abroad rather than sell or license rights for use of their assets by local firms in foreign markets.

In this vein, Dunning (1993) argues that a multinational enterprise (MNE) will develop if there are compelling reasons for a firm to internalize economic activity rather than to rely on markets. These could be related to the difficulty of exchanging company-specific assets through the marketplace. Alternately, there may be efficiency reasons for undertaking foreign direct investment (FDI). Just as a single-nation firm internalizes some economic activity for reasons of efficiency (e.g., keeping a pay division on staff rather than contracting out payroll services), so too an MNE may obtain efficiency gains by bringing together various internationally dispersed entities under common ownership. In still other cases, the opportunity to ensure a steady supply of inputs or a guaranteed market for outputs through vertical integration may be a compelling reason to internalize economic activities.

Thus, foreign investment in Canada may have changed over the last 20 years for several reasons. First, regulatory policy changes may have changed the profitability of foreign direct investment. Second, the reduction in tariffs may have influenced the relative cost of doing business in Canada and changed the incentive to internalize production.

Of course, changes in other fundamentals may also have affected foreign investment in Canada. First, outsourcing has increased in some industries—particularly in industries selling branded products where firms have learned that they can reduce costs by contracting out their manufacturing operations. This is evidence of a reduction in the benefits of internalization, which should result in a reduction of transnational investment. Second, the stability of developing markets has increased over the last 30 years and, therefore, the relative advantage of Canada as a secure source of raw materials over production facilities in developing markets has decreased. In turn, multinational investment in some sectors could have shifted away from Canada. Third, the importance of knowledge assets may have increased as the result of the type of technological progress taking place. As advanced computer-based technologies have been incorporated into the production process, knowledge assets are seen by some to have become more important.[1] This, in turn, would have increased not only the benefits from and extent of internalization, but also the amount of multinational investment in Canada.

In order to assess how these and other changes have affected the role played by foreign-controlled firms in Canada, we first investigate how their share of Canadian manufacturing sector output has changed over time. Their market shares are derived from establishment data, taken from the annual Survey of Manufactures, which classifies each plant by ownership type—domestic or foreign-controlled.[2] The changes in the importance of foreign-controlled firms in the Canadian manufacturing sector over the period 1973 to 1993 are measured using both shipments and value-added (Figure 5.1). We also report their share of labour inputs—defined as the sum of production and non-production workers.

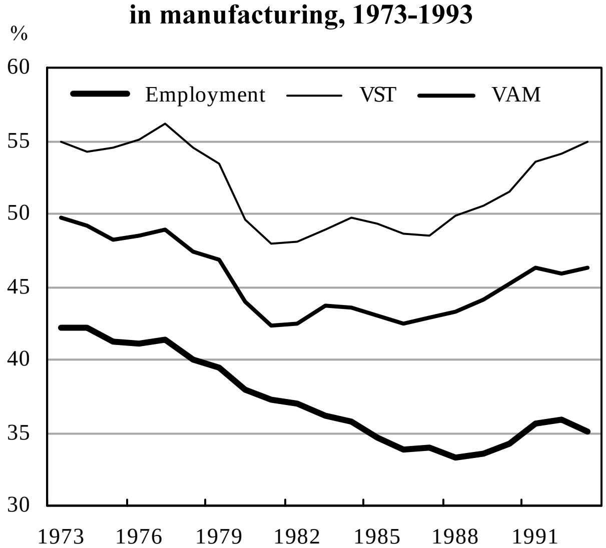
Before 1980, the share of output in manufacturing accounted for by foreign-controlled firms declined and reached low points in 1981 and 1982. Subsequently, there was a steady increase in output share. While the foreign share of output has increased, its share of employment has decreased continuously. The relative labour productivity (defined in terms of output per worker) has, therefore, increased (see Figure 5.2). Except for the two recession-related downturns, the increase has been more or less steady over the entire time period. An increase in the relative wage per worker paid by foreign-controlled plants has accompanied this increase in relative labour productivity.

Thus, the foreign-controlled sector has been holding its own with respect to output share, but its employment share has been steady or declining. As a result, labour productivity has been increasing more rapidly in the foreign than the domestic sector.

[1] Baldwin, Gray and Johnson (1996b) show that training is much more intense in firms that are adopting the new computer-based technologies.

[2] These data provide a finer level of industry detail than is provided by classifications that use firm-based data, such as those provided by the *Corporations and Labour Unions Returns Act* (CALURA).

Figure 5.1 Percentage of employment, shipments (VST) and value-added (VAM) of foreign-controlled establishments in manufacturing, 1973-1993



The aggregate data that are presented in Figures 5.1 and 5.2 may hide a great deal. It may be that changes in foreign ownership simply reflect the changing importance of different industries. Therefore, we present changes in foreign shares (shipments) across six industry sectors for three subperiods (1973-1983, 1984-1988, and 1989-1993) in Figure 5.3. These sectors are the food and beverage, natural resource, labour intensive, scale-based, product-differentiated and science-based sectors.[3] It is evident that the importance of foreign-controlled plants followed generally the same pattern in most sectors—one of decline from the 1970s to the 1980s and then a subsequent increase.

In Figure 5.4, we present the change in the relative labour productivity (measured as shipments per worker) of foreign and domestic controlled establishments in each of these sectors. Once again, there has been a general increase in the relative productivity of foreign establishments compared to domestically owned establishments.

The differences between the productivity of foreign and domestic plants can originate from different sources, such as different technologies, more capital and different plant sizes. Here we consider whether size and industry differences explain much of the differences in relative productivity and changes therein.[4] Foreign plants are larger than domestic plants and larger plants are generally more capital intensive and therefore have a higher labour productivity. Foreign plants are also more concentrated in certain sectors (scale-based) than are domestic plants (see Figure 5.3) and the latter sector is among the more capital intensive (Baldwin and Rafiquzzaman 1994).

Both of these factors would make the labour productivity of foreign plants higher than domestic plants. We can determine how much of the total difference between the two groups is the result of differences in composition by comparing the coefficients on foreign control using the following regressions:

$$\text{Log (Labour productivity)} = \alpha + \beta\ (\text{Foreign control}) \quad (1)$$

$$\text{Log (Labour productivity)} = \alpha + \delta\ (\text{Foreign control}) + \gamma\ (\text{Size}) + \eta\ (\text{Industry}) \quad (2)$$

In these equations, Foreign control is a binary variable taking on a value of 0 if domestically controlled and 1 if foreign-controlled; Size consists of three binary variables for the three groups used in this chapter—0 to 100 employees, 101 to 250 employees, and more than 250 employees—and Industry consists of five binary variables for the following sectors: labour intensive, natural resources, product-differentiated, scale-based and science-based. The five groups are defined on the basis of the primary factors affecting the competitive process in each sector. For the resource-based sector, the primary factor affecting competition is access to abundant natural resources. For the labour intensive sector, it is labour costs. For scale-based industries, it is the length of production runs. For differentiated goods, it is tailoring production to highly varied demand conditions. For science-based industries, it is the rapid application of scientific advance.

The ratio of foreign to domestic value added when no account is taken of size class or industry is provided by the coefficient attached to foreign control in equation (1)[5] and reported in columns 2 and 5 of Table 5.1. The ratio of foreign to domestic value added when account is taken of size class and industry differences is provided by the coefficient attached to foreign control in equation (2) and reported in columns 3 and 6 of Table 5.1.

To test whether the choice of output measure matters, we employ both shipments per worker and value added per worker and perform regressions (1) and (2) on micro-data derived from the Census Annual Survey of Manufactures using ordinary least squares (OLS).[6]

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[3] See Baldwin and Rafiquzzaman (1994) for a discussion of the definitions in these sectors.
[4] Globerman, Ries and Vertinsky (1994) use micro-data for a limited number of industries to argue that most of the differences relate to size and capital intensity, the latter being proxied by energy use.
[5] The value of the ratio of the labour productivity of foreign to domestic plants is given by exponent β.
[6] For this purpose, we use all production establishments.

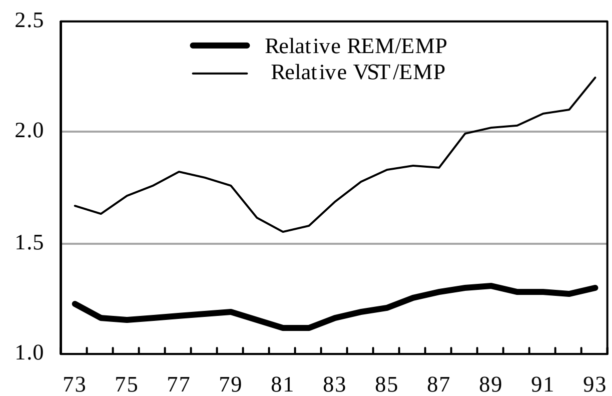
Table 5.1 The ratio of the labour productivity of foreign to domestic plants: Effect of controlling for size and industry differences, 1973-1993						
Year	Shipments per worker			Value added per worker		
	No control	Control for size and industry	Difference	No control	Control for size and industry	Difference
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1973	1.80	1.73	0.07	1.66	1.57	0.09
1983	2.09	1.90	0.19	1.92	1.73	0.19
1989	2.22	1.96	0.26	2.12	1.86	0.26
1993	2.27	1.96	0.30	2.07	1.80	0.26

Comparing the results with and without allowance for differences in size and industry reveals that size and industry account for some of the difference between foreign and domestic plants. In 1973, shipments per worker in foreign plants were 80% higher than in domestic plants when no account is taken of size and industry differences and 73% after. The comparable figures for value added per worker were 66% and 57%.

In Figure 5.2, we demonstrated that output per worker in foreign plants as a group went up relative to domestic plants using the weighted average output per worker of foreign and domestic plants. Those results are similar though not identical to the OLS results presented in column 2, Table 5.1 that use individual micro-data that do not allow for industry and size differentials. The latter shows an increase of overall foreign productivity from a level in 1973 that is 80% higher than domestic labour productivity to a level in 1993 that is 127% higher. When account is taken of size and industry composition, there still is an increase in the relative productivity of foreign-controlled plants. After size and industry controls are used, shipments per worker in foreign plants increase from 73% to 96% higher than domestic plants. Using value added per worker, the increase is from 57% to 86% (Table 5.1, column 6). Both of these increases are statistically significant.

Part of the changes in the productivity differences between the two groups arise from changes in the composition of domestic and foreign plants by size and industry. The amount that is attributed to compositional effects is found in columns 4 and 7 representing the difference between the results with and without controls for plant size and industry. It is apparent that this difference widens over time. Between 40% and 50% of the increase in the overall difference between foreign and domestic stems from this compositional shift.

Figure 5.2 Relative remuneration (REM) and shipments (VST) per employee (EMP) – foreign divided by domestic establishments, 1973-1993



These data then show that the overall differences between foreign-controlled and domestically controlled plants are not just the result of compositional shifts. It nevertheless might be the case that differences between the two groups occur disproportionately within subpopulations. In the following sections, we examine the differences in marginal labour productivity and differences in the growth rates of labour productivity across different size classes and different industries.

5.3 The conceptual framework

We are focusing primarily on differences in labour productivity and its growth across establishments that differ in terms of size and nationality, but we also divide establishments into those that are expanding and those that are contracting.

Figure 5.3 Foreign-controlled market share (VST) by sector

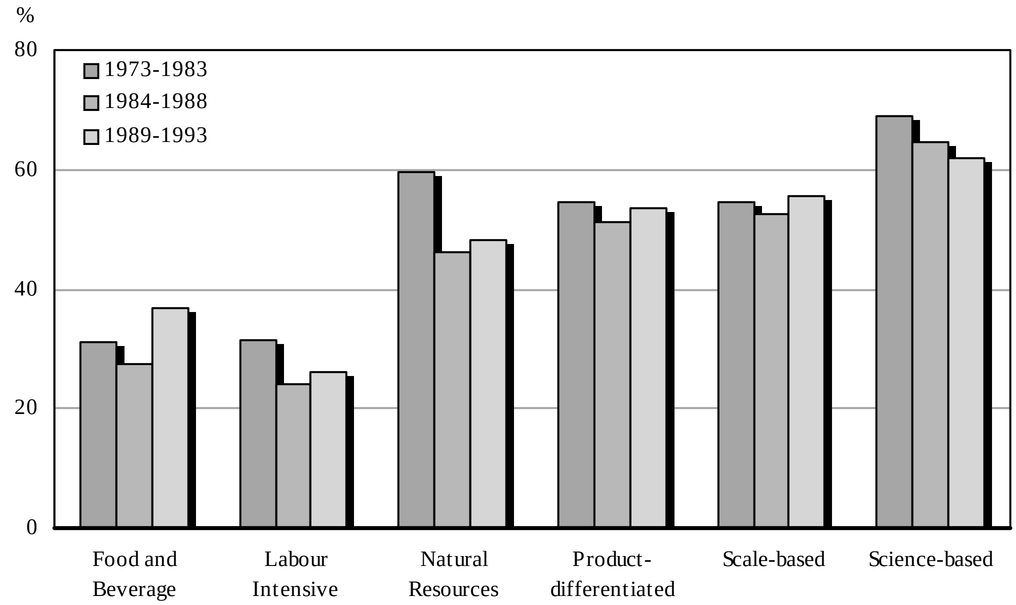
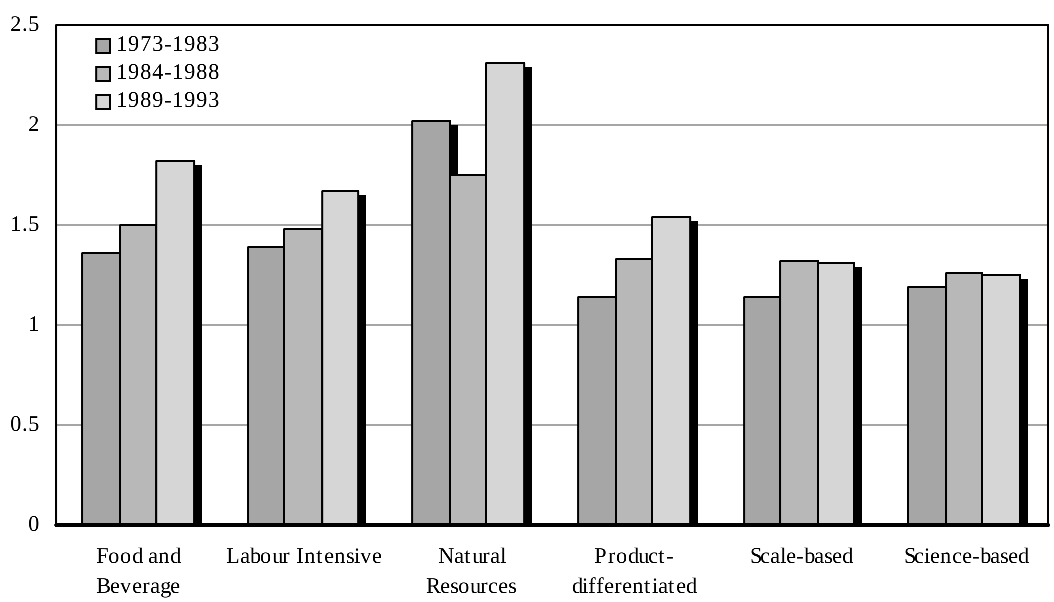


Figure 5.4 Relative output per worker – foreign relative to domestic



We do so because productivity growth is not spread evenly across all establishments. In any population of establishments, some will be increasing productivity and others will be falling behind. When those establishments that are expanding their productivity are also increasing their relative importance because they are growing in relative size, this process of expansion will contribute to productivity growth (Baldwin 1995).

Previous work has examined the proportion of productivity growth that can be attributed to different groups of establishments—entrants (Baldwin and Gorecki 1991)—or to market share being shifted from one incumbent to another (Baldwin 1995, 1996). In these previous studies, incumbents were divided into those gaining and those losing market share. Here, we initially divide the population into two different groups of establishments—those where jobs are being created and those where jobs are being eliminated.[7] This choice is determined by the intrinsic interest in each. Job creation is generally regarded favourably, job contraction, unfavourably.

As attractive as this classification may be, care must be exercised in making inferences from it about who is doing well and who is doing poorly. The job performance of firms is ineluctably connected to both output growth and productivity change. Job change at the establishment level is determined by how the demand for labour varies with output change. That very connection means that it is difficult to make generalizations about performance using job growth and job contraction categories by themselves.

For example, falling employment is sometimes seen as the sign of a failing firm. Yet, a firm that faces a stagnant market and radically changes its technology to improve productivity will often reduce employment. This type of firm cannot be characterized as a failure. Similarly, a firm that is expanding employment in lock step with expanding output would be judged to be performing well (if only employment is examined). Yet its productivity may not have changed.

Often, firms in the early stages of their life cycle focus more on product innovation than cost-cutting process innovation and they have to expand inputs dramatically just to keep up with the growth in market demand. As a market matures, continued growth requires a firm to move away from pure product innovation to process innovation. At this stage, firms implement productivity improvements that will reduce unit costs and allow them to expand output during the mature phase of the market when price competition becomes more important as a marketing instrument. A firm that fails to achieve unit cost reductions via productivity improvements will not survive the transition from the early to the later stages of market development.

At any time, the population is made up of some firms that are in the early phases of market development, and others that are in the later stages, operating in relatively mature markets. If firms are adapting successfully to the later stages of the life cycle, they will be increasing productivity and reducing unit costs by reducing their requirements for labour per unit of output, for example. Often this is done by increasing capital intensity. Sales of firms at this stage may also have reached a plateau. Other firms will be in their growth phase, when it is all they can do to keep up with growing demand, where innovative activities focus more on product innovation than on cost-based process innovations. The latter group of firms will probably have less productivity growth because they are still expanding rapidly and have not yet moved to the mature phase of the market where competition is based more on prices than on new-product introduction.

Therefore, a decline in employment in a firm is not necessarily evidence of the decline of the firm. It may be associated with productivity gains during the mature phase of the life cycle. An examination of employment change alone does not allow us to conclude the reasons for employment change. If we are to study employment change and how firms respond to output change, we must be cognisant of the extent of heterogeneity in the population and the various reasons that a firm may be increasing or decreasing employment.

5.4 Data description

The data used in this analysis are taken from the microeconomic records collected by the Census Annual Survey of Manufactures and a longitudinal database that was created by the Micro-economic Analysis Division, covering the period 1973-1993. Focusing on establishment data is advantageous because it allows us to move closer to the product or business line than would be the case if firm-level data were used. Because firms are constantly merging and divesting themselves of plants, a good portion of their growth occurs as a result of these control changes. For this analysis, we want to avoid these effects.

[7] Bailey, Bartelsman and Haltiwanger (1996) also use this distinction.

In this data set, the records for individual establishments are linked through time, allowing the dynamics of establishments to be investigated.[8] The establishments can be classified by four-digit industries using the Standard Industrial Classification (SIC) system, nationality of control (domestic versus foreign),[9] and size (small, medium, and large).[10] The size codes were assigned each year, allowing establishments to switch from one size category to another as they grow or downsize over time. The four-digit SIC industry codes were grouped into five broad sectors—natural resources, labour intensive, scale-based, product-differentiated and science-based. The natural resource sector was further partitioned into two subsectors—food and beverage and 'other' natural resource industries. In all, these classification criteria grouped the manufacturing establishments into 36 categories; i.e., 6 sectors, 3 size classes and 2 types of control (Canadian and foreign).

Establishments were grouped into those where employment was increasing and those where employment was decreasing. Employment, employment changes, shipments, and shipment changes were calculated at the level of the 36 categories.[11] For example, one data set consisted of job growth and output change for each of these 36 categories for 20 years; the other for job loss and associated output change. Job growth encompassed both entries and changes in continuing establishments. Job contraction consisted of both exits and changes in continuing establishments.

In this chapter, it is assumed that labour productivity will grow because of increases in the inherent efficiency of a firm, as well as increases in the amounts of other inputs that are combined with labour—in particular the amount of capital that is available per unit of labour.

Change in output is measured in terms of changes in total shipments. Employment is measured as the total number of workers (salaried plus production workers). Alternatives could have been chosen; for example, we could have used value added as defined in the Census Annual Survey of Manufactures. The latter concept includes some purchased services and thus is not identical to the net value added concept that is used in generating GDP and the values used in the official productivity statistics. Shipments as a measure of output, has the disadvantage that increases in shipments per worker may simply hide a decrease in the degree of vertical integration over time. For the purposes of this analysis, it turned out not to matter much which measure of output was used, and, therefore, we have chosen to report the measure used herein.[12]

Changes in shipments were expressed in real terms, with the nominal values of each establishment being deflated by the four-digit output price index for the industry in which the establishment is classified.

This chapter examines changes in labour productivity over time. These changes are investigated for short time periods and longer time periods since experience has shown that the former are expected to heavily reflect random events and the latter are more useful for distinguishing trends (Baldwin and Gorecki 1990). The short-run analysis is based on a year-to-year change in the relevant variables, generating a time series for the period 1973-1993. For the long-run analysis, the changes are measured using a five-year moving average, generating a time series of 16 observations for the 1973-1988 period. Establishments were allowed to move freely from one time period to the next between the job creation and job elimination categories.

5.5 Labour productivity

This section investigates how the productivity of labour changes as a result of the growth and contraction process. Growth and contraction are treated separately. The population is divided into those with growth and contraction in output as opposed to growth and contraction in employment to avoid selection effects when estimating marginal labour productivities (Hamermesh 1993 and Heckman 1979).[13]

[8] Baldwin and Gorecki (1990) provide details on the creation of the data set.

[9] Corporations are assigned a country of control under CALURA based on the country of residence of the persons having the greatest potential to strategically influence the activities of the corporations.

[10] Small: 0 to 99 employees; medium: 100 to 499 employees; and large: 500+ employees.

[11] Grouping was done to reduce the errors in measurement that occur at the level of the individual establishment.

[12] Shipments were chosen because price indices for products that can be used for deflation are superior to those available for deflating value added. In addition, shifts in the composition of the Census Annual Survey of Manufactures that change the proportion of establishments reporting value added using the long form as opposed to the short form potentially cause some bias in value-added comparisons that are not corrected for these shifts.

[13] See Baldwin and Dhaliwal (2000) for a related study that estimates the marginal labour productivity from the same set of data used here. In the estimation of marginal labour productivity, selection effects are serious. They turned out not to be important for the results reported here. Generally, the cells with negative employment change are also those with negative output change. Nevertheless, we use the same categories here that were used in the earlier paper in order to provide comparability to the other paper.

Table 5.2 Effect of changes in employment and output on average labour productivity in the Canadian food and beverage sector, 1973-1993

Plant category	ΔLP_j Growing plants		ΔLP_j Contracting plants		ΔLP_j All plants	
(Control and size)	Mean	Standard error	Mean	Standard error	Mean	Standard error
Short run						
Canadian control						
– small	0.88	0.011	1.17	0.010	0.99	0.009
– medium	1.00	0.005	1.07	0.010	1.03	0.006
– large	1.02	0.010	1.05	0.019	1.03	0.009
Foreign control						
– small	0.93	0.018	1.10	0.014	0.99	0.012
– medium	1.02	0.012	1.07	0.014	1.04	0.011
– large	1.02	0.012	1.07	0.018	1.04	0.011
Long run						
Canadian control						
– small	0.91	0.021	1.29	0.016	1.06	0.023
– medium	1.08	0.016	1.15	0.015	1.10	0.014
– large	1.04	0.013	1.08	0.018	1.05	0.013
Foreign control						
– small	1.04	0.025	1.19	0.029	1.12	0.018
– medium	1.13	0.026	1.36	0.087	1.19	0.028
– large	1.15	0.045	1.23	0.042	1.18	0.035

The analysis is performed for both the short run and long run. The scope of this analysis is restricted to the food and beverage sector and the rest of the manufacturing industries; the latter combines the natural resources, labour intensive, scale-based, product-differentiated and science-based industries into one group.

The change in labour productivity (ΔLP_j) is expressed in ratio form. The formula is:

$$\Delta LP_j = LP_{t+j} / LP_t$$

where

LP_t = total shipments in period t divided by the total employment in period t,

LP_{t+j} = total shipments in period t+j divided by the total employment in period t+j,

t = the 1973-1992 period for the short run (annual) analysis or 1973-1988 period for the long run (five-year) analysis, and

j = 1 for the short run (annual) analysis or 5 for the long run (five-year) analysis.

ΔLP_j is calculated for growing, declining and all establishments together, and in each case by size and control. In each case, the shipment and employment data correspond to a particular group of establishments (defined in terms of sector, control and size). All shipments are measured in real terms by dividing the nominal values at the establishment level by the output price index of the corresponding four-digit (1980 SIC) industry.

ΔLP_j equals one when the marginal changes in output and employment do not alter labour productivity. For example, when scale economies are absent, the capital-to-labour ratio of the plant remains unchanged, or no efficiency improvements take place. When ΔLP_j is greater than one, labour productivity has improved as a result of the marginal changes in employment and output changes. For growing establishments, this happens when a given increment in employment is accompanied by a relatively larger expansion in output. This could occur when plants adopt advanced technologies or become more capital intensive. The presence of significant scale economies could also result in an improvement in the efficiency of all inputs, including labour. Finally, it could occur if employment expansion is concentrated in operations that bring the largest marginal gain in performance and profitability.

For the contracting segment of establishments, a gain in labour productivity ($\Delta LP_j >1$) occurs when a contraction in output is accompanied by a relatively large contraction in employment. This could arise because the most inefficient operations are closed down first, or alternatively, the least productive members of the labour force are let go first. The gain in labour productivity for contracting plants could also occur as the result of a restructuring that boosts the capital-to-labour ratio.

Figure 5.5 Long-run growth in labour productivity in the food and beverage sector

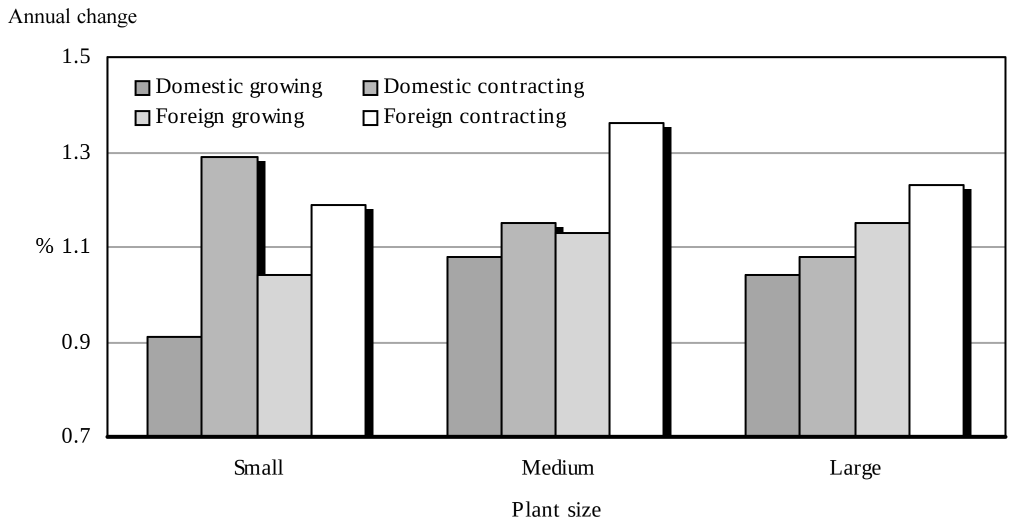


Figure 5.6 Long-run growth in labour productivity: Food and beverage versus all other manufacturing

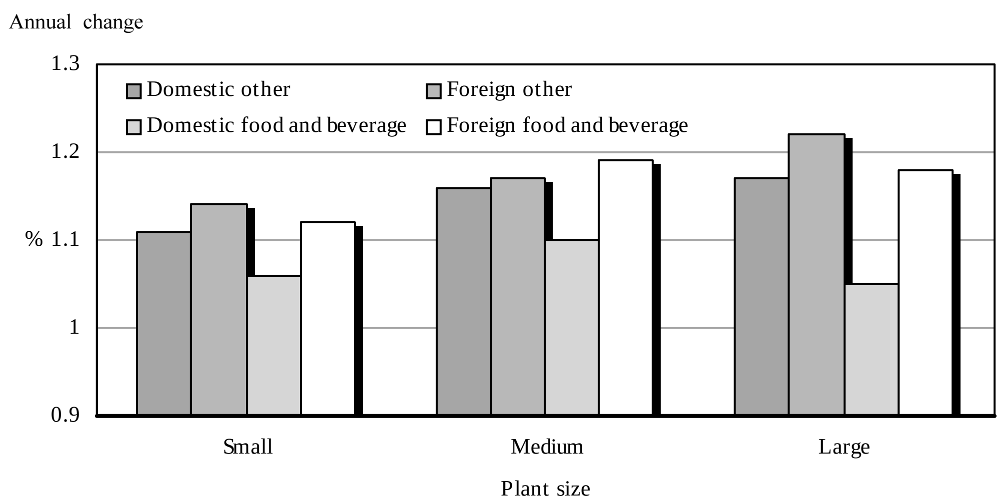


Figure 5.7 Long-run growth in labour productivity in all other manufacturing

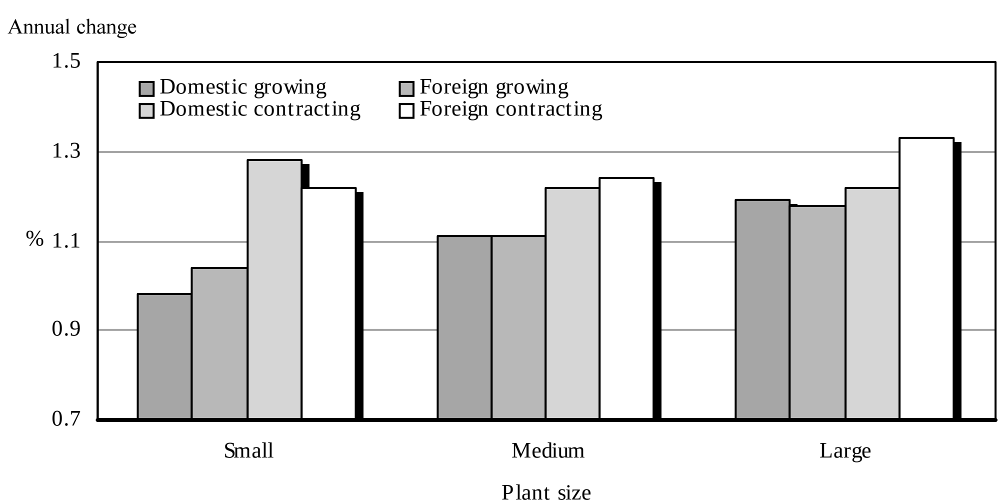


Table 5.3 Changes in labour productivity in the Canadian manufacturing sector excluding food and beverage industries, 1973-1993

Plant category	ΔLP_j Growing plants		ΔLP_j Contracting plants		ΔLP_j All plants	
(Control and size)	Mean	Standard error	Mean	Standard error	Mean	Standard error
Short-run						
Canadian control						
– small	0.91	0.006	1.17	0.008	1.01	0.005
– medium	1.01	0.006	1.08	0.009	1.04	0.006
– large	1.04	0.007	1.05	0.010	1.04	0.007
Foreign control						
– small	0.94	0.019	1.10	0.009	1.01	0.011
– medium	1.01	0.011	1.08	0.008	1.04	0.006
– large	1.02	0.010	1.09	0.017	1.05	0.007
Long-run						
Canadian control						
– small	0.98	0.009	1.28	0.014	1.11	0.008
– medium	1.11	0.013	1.22	0.024	1.16	0.011
– large	1.19	0.015	1.22	0.027	1.17	0.015
Foreign control						
– small	1.04	0.025	1.22	0.018	1.14	0.023
– medium	1.11	0.012	1.24	0.017	1.17	0.011
– large	1.18	0.024	1.33	0.040	1.22	0.020

A loss in or deterioration of labour productivity occurs when ΔLP_j is less than one. In the expansion phase, this could occur when mature or less efficient plants (either new entrants or firms that are in the early stages of the product cycle) are responsible for most of the expansion in output. In the contraction phase, it could happen if downsizing significantly reduces the efficiency of all production factors. Fixity of labour inputs could also cause labour productivity to decline when output falls.

Examining changes in productivity in both short and long run, by size class and by nationality of control reveals important information about differences in the growth process within the establishment population. The differences between the short and long run reveal the importance of input fixities, factor substitution, technology development and scale economies. The distinction by nationality of control (domestic versus foreign) captures the influence of firm-specific factors, such as technology, management, and other factor costs. Size differences allow us to understand the respective contribution of small versus large establishments.

Mean values of productivity gains and losses

The short- and long-run mean values of ΔLP_j (averaged over the sample period) for growing plants, contracting plants and all plants taken together—and in each case broken down by control and size—are reported in Table 5.2 for the food and beverage industries and Table 5.3 for the rest of the manufacturing sector.

Food and beverage sector

Generally, growing establishments have less increase in labour productivity than those contracting (Table 5.2). In the short run, the annual increase in the labour productivity for contracting plants ranged from 5% to 17%, while in the long run it was in the 8% to 36% range. In contrast, expanding plants in each category showed less of an increase in labour productivity and actually a decline in the smallest size class.

The net effect of growing and contracting plants on the overall labour productivity of the food and beverage sector reveals that the strong positive showing of establishments in the contraction phase outweighs their relatively weak or negative showing in the expansion phase. As a result, there was an overall improvement in labour productivity in almost all segments of the sector (Figure 5.6). The only exceptions are small plants where the marginal changes are almost productivity-neutral in the short run.

These differences in the growth and contraction categories capture disparities that arise because firms are at different stages in their life cycles and are being affected differently by macro-economic effects. The fact that these differences exist, whether we look at the short run or long run, suggests that the former outweigh the latter—that what we see here is primarily related to the life-cycle effect.

There are also substantial disparities across size classes, and these differences operate in different directions for growing and contracting plants. For domestic growers, larger size classes increase productivity the most, and the smallest size classes, the least. The reverse is true for the contracting domestic class of plants. This difference comes primarily from the behaviour of the smallest size class—the class that contains most of the entry and exits of establishments that take place in the population. It is in this class that labour productivity falls for growing establishments and declining establishments have much higher labour productivity growth than both of the other two size classes. This peculiar result arises from the importance of entry and exit herein and the fact that new establishments initially are less productive than incumbent establishments and that most of the inefficient subsequently exit (see Baldwin and Rafiquzzaman 1995). The appearance of entrants in the smallest size classes drags down productivity therein and their demise has the opposite effect. On balance, however, their net effect (the 'All plants' column, Table 5.2) is neutral in the short run for the smallest classes. On the other hand, the larger size classes have a larger positive increase in the short run when both growing and contracting plants are averaged.

In the long run, some of the size-class effect is reduced as small establishments grow and improve their relative importance and as the largest size class reduces its performance, so that the two are about the same. The middle size class showed the largest improvements in labour productivity for domestic establishments.

The same gradations across size classes can also be discerned for foreign-controlled establishments. The net effect observed in the smallest size class is also essentially neutral in the short run, but it increases more in the long run for the foreign-controlled sector—but then it does so across all size classes. It is in the foreign sector that the largest differences occur across size classes. This occurs not so much because small establishments make little progress, but rather because the largest establishments have such large productivity increases.

Foreign establishments generally have higher rates of productivity increases. The domestically controlled establishments improved their overall labour productivity by about 3% in the short run and by between 5% and 10% in the long run. The gains are relatively higher at plants managed from abroad; they range from 4% in the short run to almost 18% in the long run. The one category where foreign-controlled labour productivity increases are not higher is for contracting plants in the smallest size class where exit effects are quite different. This is because foreign-controlled entrants tend to be relatively more productive and the same degree of churning owing to entry and exit does not occur in new foreign-controlled establishments.

The differences between domestic and foreign sectors are generally higher in the long than in the short run for each size class. This suggests that the differences that exist between the foreign and domestic sectors are difficult to see in the short run because of similar reactions to macro-economic fluctuations, but that over time growth tends to become more differentiated between the two groups.

Other manufacturing sector

For the rest of the manufacturing industries, the pattern of changes across both growing and contracting, small and large, and domestic and foreign-controlled groups are quite similar to those of the food and beverage sector discussed above.

First, larger plants experience greater increases in labour productivity than the smallest plants, which experience little change on balance (Figure 5.7). However, the size effect is more noticeable in the other manufacturing industries, in that the largest-size class experiences increases that are at least as large as the middle-size classes.

Second, foreign-controlled plants always perform better than domestic plants in the food and beverage sector. But the benefit of being controlled from abroad is slightly less in the rest of the manufacturing sector. For plants that expanded in the long run, the foreign-controlled small, medium and large plants led their Canadian counterparts by 13, 5 and 11 percentage points in the food and beverage industries and only 6, 0 and -1 percentage points in the rest of the manufacturing sector, respectively.

Finally, the net result of labour-output adjustment on labour productivity is always positive for all segments of the rest of the manufacturing sector and ranged from 1% to 5% in the short run and from 11% to 22% in the long run. These net gains are generally higher than those in the food and beverage industries (Figure 5.6).

Trends in the impact of size and nationality of control on labour productivity growth

Of critical interest is the extent to which the differences outlined in the previous section across size classes and nationality of control have changed.

During the period studied, Canada's economy became more open. Tariff rates fell and trade as a percentage of GDP increased. This may have allowed Canadian-controlled plants to increase their scale and improve their relative productivity. Yet, technological change has been rapid, and with the spread of new computer-based technologies (Baldwin and Sabourin 1995), foreign-controlled plants have been quicker to make use of these new technologies

Table 5.4 Impacts of size and control on changes in labour productivity, Canadian food and beverage sector

Explanatory variable	Short run			Long run		
	Growing plants	Contracting plants	All plants	Growing plants	Contracting plants	All plants
Intercept	0.94 (0.019)***	1.14 (0.024)***	1.024 (0.015)***	1.034 (0.036)***	1.25 (0.070)***	1.162 (0.031)***
Trend	-0.0055 (0.002)***	0.0003 (0.0022)	-0.0036 (0.0013)***	-0.0147 (0.004)***	-0.0078 (0.0079)	-0.017 (0.0035)***
S_2	0.0485 (0.023)**	-0.063 (0.0293)**	-0.0014 -0.0083	0.074 (0.045)*	-0.044 (0.0856)	-0.021 (0.038)
S_3	0.0543 (0.023)**	-0.092 (0.0293)***	-0.0057 (0.0083)	0.0003 (0.045)	-0.121 (0.0856)	-0.104 (0.038)***
CF	0.0013 (0.0185)	-0.038 (0.0239)	-0.0078 (0.015)	-0.038 (0.036)	-0.046 (0.070)	-0.031 (0.031)
S_2*Trend	0.0060 (0.0020)***	-0.0002 (0.0026)	0.0043 (0.002)***	0.0073 (0.005)	0.0077 (0.0097)	0.0104 (0.004)**
S_3*Trend	0.0067 (0.0020)***	0.0014 (0.0026)	0.0047 (0.002)***	0.0155 (0.005)***	0.0050 (0.0097)	0.0169 (0.004)***
CF*Trend	0.014 (0.002)	0.0023 (0.0022)	0.0017 (0.0013)	0.018 (0.004)***	0.0178 (0.0079)**	0.0167 (0.0035)***
R^2	0.53	0.20	0.20	0.48	0.11	0.43

Note: Three asterisks (***), two asterisks (**) and one asterisk (*) represents the significance of the coefficient at 99%, 95% and 90% levels, respectively.

(Baldwin and Diverty 1995; Baldwin and Sabourin 1997). It is, therefore, of considerable interest to know whether the productivity advantage of foreign establishments has been trending upward.

At the same time, the extent to which productivity differences have been changing across size classes is of interest since an increasing amount of employment is found in smaller establishments (Baldwin and Picot 1995). However, small establishments tend to be slow when adopting new technologies (Baldwin and Sabourin 1995; Baldwin and Diverty 1995) and the relative productivity of small establishments has fallen over the period (Baldwin 1998). The decline in relative productivity, combined with the increasing share of employment in this group, has accounted for part of the productivity slowdown experienced by the Canadian manufacturing sector (Baldwin 1996).

Investigating whether this decline is simply the result of the increasing importance of small domestic plants or whether it is the result of peculiarities of specific subsectors requires that changes in labour productivity be tracked over time and compared across size classes, industry and nationality of control.

To do so, we tested whether changes in labour productivity exhibited any time trend, and whether these trends are statistically different by nationality of control and by size class. We employed the following regressions on the time series data used to construct the mean values given in Tables 5.2 and 5.3.[14] The length of time is 1973-1992 for the annual growth and 1973-1988 for the five-year growth. The regression used was

$$\Delta LP_j = f\,(S_2, S_3, CF, \textsc{Trend}, S_2{*}\textsc{Trend}, S_3{*}\textsc{Trend}, CF{*}\textsc{Trend})^{15}$$

where Trend is a variable taking values from 0 to 19 for the annual changes and from 0 to 15 for the five-year changes; S_2 and S_3 are binary variables for medium and large size plants, and nationality (CF) is a binary variable

[14] The pooled regression corrected for first-order serial correlation, contemporary correlation across categories, and heteroscedasticity.
[15] We also experimented with interaction terms between the size variables and the foreign-control variable. This did not affect our results in any meaningful fashion.

Table 5.5 Impacts of size and control on trends in labour productivity, Canadian manufacturing sector excluding food and beverage industries

Explanatory variable	Short run			Long run		
	Growing plants	Contracting plants	All plants	Growing plants	Contracting plants	All plants
Intercept	0.962 (0.017)***	1.12 (0.017)***	1.017 (0.011)***	1.04 (0.027)***	1.231 (0.039)***	1.136 (0.024)***
Trend	-0.0039 (0.0016)**	0.0024 (0.0015)	-0.0007 (0.0010)	-0.0067 (0.0031)**	0.0008 (0.0044)	-0.0035 (0.0027)
S_2	0.0037 (0.021)*	-0.067 (0.021)***	0.0039 (0.013)	0.051 (0.033)	-0.068 (0.0473)	-0.0038 (0.029)
S_3	0.046 (0.021)**	-0.095 (0.0207)***	0.0017 (0.013)	0.085 (0.033)**	-0.1045 (0.0473)**	-0.032 (0.0289)
CF	-0.013 (0.017)	-0.0154 (0.069)	-0.0067 (0.0110)	-0.044 (0.027)	0.0301 (0.0386)	0.0067 (0.0236)
S_2*Trend	0.005 (0.0019)***	0.0014 (0.0019)	0.0029 (0.0012)**	0.0066 (0.0037)*	0.0060 (0.0054)	0.0057 (0.0038)
S_3*Trend	0.007 (0.0019)***	0.0033 (0.0019)*	-0.0035 (0.0012)***	0.0121 (0.0037)***	0.0170 (0.0054)***	0.0140 (0.003)***
CF*Trend	0.0013 (0.0015)	-0.0003 (0.0015)	0.0008 (0.0009)	0.0082 (0.0031)***	-0.0007 (0.0044)	0.0052 (0.003)*
R^2	0.16	0.10	0.08	0.20	0.04	0.12

Note: Three asterisks (***), two asterisks (**) and one asterisk (*) represents the significance of the coefficient at 99%, 95% and 90% levels, respectively.

for foreign-controlled plants. The results for the food and beverage industries are presented in Table 5.4 and for the rest of the manufacturing sector in Table 5.5. Below we discuss results for the long-run analysis only. We further restrict our discussion by comparing the results for small and large size plants since the performance of the medium size plants generally falls between the two polar categories.

Food and beverage sector

In the previous section, we showed that large growing plants had a significant edge over their small counterparts in terms of the effect of marginal changes on labour productivity; on average, it was 14 and 9 percentage points for Canadian and foreign-controlled plants, respectively. The regression results presented in Table 5.4 show that the gap between the two rates of change widens over time (the negative coefficient on TREND, which captures the trend in small plants and the positive coefficient for S_3*TREND representing large plants).

For contracting plants, productivity improvements were larger for small plants than for large plants. The difference between the two was 12 percentage points for the Canadian plants and 3 percentage points for the foreign-controlled plants, thereby indicating that this phenomenon was being driven primarily by the domestic sector. This gap in labour productivity gain is stable over time—all coefficients involving TREND are insignificant in both the short and long run.

The net effect of growing and contracting plants is reflected in the coefficients in the all-plants regression. Here, the gap between small and large plants gets larger over time in that the trend variable (representing the small sector) has a significantly negative coefficient and that the TREND variables for the middle- and largest-size classes are positive and significant. This result is largely being driven by the size-class differences in the growing sector.

The difference between domestic and foreign-controlled plants at the beginning of the period was not statistically significant (the coefficient on CF is insignificant). However, the difference between the two increases over time (the coefficient on CF*TREND is positive and significant everywhere). Thus, the effect of foreign control on the rate of increase in labour productivity has grown larger over the period studied here.

Manufacturing sector excluding food and beverage sector

The results for the rest of the manufacturing sector are very similar to those for the food and beverage sector discussed above. In both cases, small growing establishments are less productive than their large counterparts and the trend over time increases the difference. Differences occur between food processing and the rest of the manufacturing sector in downsizing plants. Large plants in the more aggregated sector tend to become more and more successful downsizers over time whereas this effect is not significant in food and beverage. The coefficient on S_3*TREND is positive and significant in the rest of the manufacturing sector whereas it is positive but insignificant for food and beverage.

Although the results of Table 5.5 aggregate sectors together, we also examined the trend at each of the sectoral levels—for natural resources, scale-based, labour-intensive, product differentiated and science-based industries. The trend variable for the largest-size class is positive and significant for all but the labour intensive sector. The size effects that have been reported are found across a wide range of industries.

As in the food and beverage sector, the gap between foreign-controlled and domestic establishments in the rest of the manufacturing sector increased over time (as indicated by the positive and significant coefficient on CF*TREND in Table 5.5). While this trend is not evident in the contracting sector, it is found in the all-plants equation. However, the effect of foreign control is stronger, more significant, and more widely spread across both growing and contracting plants in the case of the food and beverage industries than for other sectors. Elsewhere, this nationality effect is strongest and most significant in the scale-based, the product differentiated, and the natural resources sectors.

5.6 Conclusion

If we are to study employment growth and how firms are responding to output changes, we must be cognizant of the extent of heterogeneity in the population. That is the reason we have divided the population here into establishments that are increasing their demand for labour and those that are contracting their labour force.

There are substantial differences in the pattern of labour productivity increases across these two groups of plants. Labour productivity has increased more over time for contracting plants than for growing plants, for large as opposed to small plants and for foreign as opposed to domestic plants. Restructuring that has seen the decline (in terms of share of employment) of large plants and a decline in the importance of foreign-controlled plants (in terms of share of employment) would have slowed productivity growth.

It is noteworthy that it is not only a shift in share of employment from one group to another that has caused this decline. The differences between small and large establishments and domestic and foreign plants have increased over the period of the study. Whether this is caused by a change in technology or in capital intensity, or is ascribed to some other factor, cannot be ascertained from this study. We do know that these groups differ in terms of their application of advanced computer based technologies. We also know that variables like average wage rates have been increasing in those plants that employ these technologies relative to those that do not (Baldwin, Gray and Johnson 1996a; Baldwin and Rafiquzzaman 1998). The changes in labour productivity may reflect these technological differences.

It is also evident that these changes take place slowly. The trends in relative labour productivity, whether in terms of differences across size-classes or differences across nationality groups, have developed slowly, but there is little doubt about the direction of the trend.

References

Bailey, M., E.J. Bartelsman and J. Haltiwanger. 1996. "Downsizing and Productivity Growth: Myth or Reality." *Sources of Productivity Growth.* D. Mayes (ed). Cambridge: Cambridge University Press. 263-288.

Baldwin, J.R. 1995. *The Dynamics of Industrial Competition*. Cambridge: Cambridge University Press.

———. 1996. "Productivity Growth, Plant Turnover and Restructuring in the Canadian Manufacturing Sector." *Sources of Productivity Growth.* D. Mayes (ed). Cambridge: Cambridge University Press. 245-262.

———. 1998. "Were Small Firms the Engines of Growth in the 1980s?" *Small Business Economics.* 10: 349-364.

Baldwin, J.R. and B. Diverty. 1995. *Advanced Technology Use in Manufacturing Establishments.* Research paper no. 85.Ottawa: Statistics Canada, Analytical Studies Branch.

Baldwin, J.R. and N. Dhaliwal. 2000. *Labour Productivity Differences Between Domestic and Foreign-Controlled Firms in the Canadian Manufacturing Sector.* Research paper no. 118. Ottawa: Statistics Canada, Analytical Studies Branch.

Baldwin, J.R. and P.K. Gorecki. 1990. *Structural Change and the Adjustment Process: Perspectives on Establishment Growth and Worker Turnover.* Ottawa: Economic Council of Canada.

———. 1991. "Entry, Exit and Productivity Growth." *Entry and Market Contestability: An International Comparison*. P. Geroski and J. Schwalbach (eds). Oxford: Basil Blackwell. 244-256.

Baldwin, J.R., T. Gray and J. Johnson. 1996a. *"Technology-Induced Wage Premia in Canadian Manufacturing Plants During the 1980s."* Research paper no. 92. Ottawa: Statistics Canada, Analytical Studies Branch.

———. 1996b. "Advanced Technology Use and Manufacturing in Canadian Manufacturing." *Canadian Business Economics.* 5: 51-70.

Baldwin, J.R. and G. Picot. 1995. "Employment Generation by Small Producers in the Canadian Manufacturing Sector." *Small Business Economics.* 7: 317-331.

Baldwin, J.R. and M. Rafiquzzaman. 1994. *Structural Change in the Canadian Manufacturing Sector: 1970-1990*. Research paper no. 61. Ottawa: Statistics Canada, Analytical Studies Branch.

———. 1995. "Selection versus Evolutionary Adaptation: Learning and Post-Entry Performance." *International Journal of Industrial Organization*. 13: 501-522.

———. 1998. "The Effect of Technology and Trade on Wage Differentials Between Non-Production and Production Workers in Canadian Manufacturing." *Innovation, Industry Evolution and Employment,* D. Audretsch and R. Thurik (eds). Cambridge: Cambridge University Press.

Baldwin, J.R. and D. Sabourin. 1995. *Technology Adoption in Canadian Manufacturing.* Catalogue no. 88-512-XPB. Ottawa: Statistics Canada.

———. 1997. "Technology Adoption in Canadian Manufacturing: A Comparison across Plant Sizes." A paper given to the 7th International Conference on Management of Technology. Manchester: England.

Caves, R.E. 1982. *Multinational Enterprise and Economic Analysis*. Cambridge: Cambridge University Press.

Dunning, J.H. 1993. *Multinational Enterprises and the Global Economy*. New York: Addison-Wesley.

Globerman, S., J.C. Ries and I. Vertinsky. 1994. "The Economic Performance of Foreign Affiliates in Canada." *Canadian Journal of Economics.* 27: 143-156.

Hamermesh, D.S. 1993. *Labor Demand*. Princeton, N.J.: Princeton University Press.

Heckman, James J. 1979. "Sample Selection Bias as a Specification Error." *Econometrica.* 47,1: 153-161.

6 The Structure of Investment in Canada and its Impact on Capital Accumulation

John R. Baldwin and Tarek M. Harchaoui

6.1 Introduction

From an average of 24% of GDP in the 1960s and 1970s, gross savings in Canada fell to roughly 18% in the 1990s.[1] This decline has been a source of concern to some as it affects the investment-to-GDP ratio, and investment is seen to hold the key to productivity growth. A concomitant slowdown in Canadian productivity since 1973 has supported these concerns. They have been reinforced by international comparisons that typically show Canada towards the bottom in terms of both its national savings rate and its productivity growth rate (Bosworth 1990; Edwards 1995).

This chapter investigates three issues related to investment spending since the early 1960s.

- First, how does the decline in the Canadian savings rate relate to investment spending in different areas? Has it primarily affected machinery, structures, housing, or government investment?
- Second, has the reduction in savings resulted in a dramatic change in the sources of financing on which investment relies? Here we ask whether financial constraints are related to the historically low level of the business sector's investment-to-output ratio during the recent expansion period.
- Third, has the reduced level of investment affected the Canadian economy's long-run trend to increase the amount of capital available per worker? Was investment sufficient to augment the capital-to-labour ratio during the recent decades?

Section 6.2, which examines patterns of savings and investment for the 1961-1999 period, shows that the impact of declining national savings on Canada's business investment has been cushioned, because decreases in housing and government investment absorbed a substantial part of the decrease in spending. Moreover, the cutbacks that have occurred in business investment have been concentrated in structures, not equipment.

Section 6.3 investigates access to finance and asks whether there is evidence that restrictions on savings have led the business community to turn to new sources of funds. It finds that internal funds have been more than enough to finance fixed investment in recent years.

Section 6.4 examines the impact of changes in the structure of investment on the amount of capital available per worker. While the capital-to-labour ratio for most industries experienced rapid growth in recent years, the overall capital stock per worker grew at a somewhat slower pace than in the past. The relatively modest increase in the capital-to-labour ratio of the business sector is not the result of a restructuring away from goods to services.

6.2 Patterns of investment in Canada

Analysis at the aggregate level

In the Canadian System of National Accounts, savings, by definition, equals investment. A decline in savings as a percentage of GDP necessarily translates into a decline in investment.

[1] Gross saving is defined as the sum of saving and capital consumption allowances. See Statistics Canada (1998). The data used in this chapter came from various sources published by Statistics Canada. The investment series are from the Income and Expenditure Accounts Division and the Input Output Division; the financial statistics are from the Income and Expenditure Accounts Division; the labour data are from the Micro-economic Analysis Division; the capital stock series are from the Investment and Capital Stock Division. The U.S. data on investment are published by the Bureau of Economic Analysis.

Figure 6.1 Gross investment, share of GDP (in current prices)

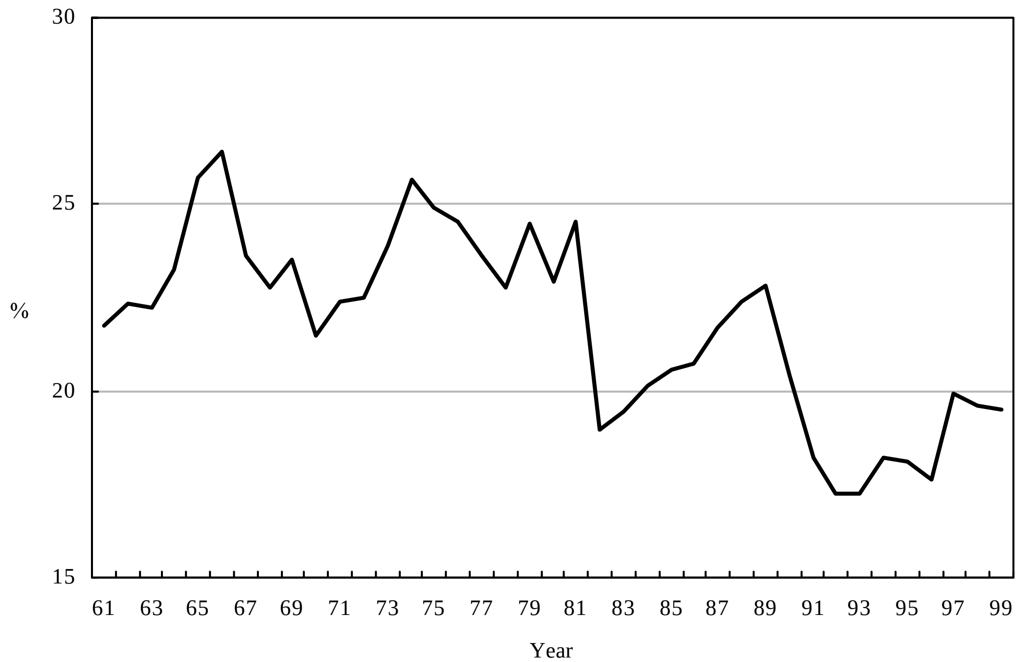


Figure 6.2 Gross investment by component, share of GDP (in current prices)

In this chapter, we start by examining the course of the ratio of investment to output over time. These ratios tell us whether the amount of total GDP devoted to investment is being held constant over time. It is also of interest to examine the growth in real capital stock or in real capital per worker, but these are topics that are addressed elsewhere and at the end of this chapter.

We start by using ratios calculated in nominal dollars, rather than ratios calculated in real dollars because the latter inherently do not make sense for our purpose (see also Ehemann, Katz and Moulton, 2000; Whelan, 2000). They do not make sense because we are interested in asking how much of today's resources are being devoted to investment and how that compares to previous years. A real ratio that uses a set of base prices from a previous period compares the expenditures on investment using a previous set of prices and essentially tell us whether holding prices constant, we would be increasing or decreasing the percentage of total expenditures to investment. However, we are not interested in whether we could spend considerably less on investment if we had to pay for the investment using prices in a prevous period. We are asking what percentage of the resources presently available are devoted to investment—and for that we need to use current price ratios throughout.

There are other more practical reasons to avoid ratios of investment to GDP using real ratios. First, price deflators for machinery and equipment are probably less precise than those for consumption. Secondly, we are interested in cross-country comparisons of investment of GDP and the price indices used in different countries are not always calculated the same way. For example, Canada uses a Paasche price index and the U.S. derives a Fisher price index. In periods of rapid technological change, these indices will be quite different.

Investment is made up of a number of components. Investment includes not only the business expenditures on equipment and non-residential structures that are the focus of most concerns about output and productivity growth, but also residential investment, government investment and business inventories.

The overall investment rate averaged 23.5% of GDP from 1961 to 1969, but it fell to 18.6% between 1990 and 1999 (Figure 6.1). Reductions in the fraction of GDP devoted to investment in housing, government structures and equipment, inventories, and non-residential structures have been the primary effects of declining savings. The share devoted to residential housing was relatively constant, averaging 5.3% of GDP at the beginning and end of the period (Figure 6.2). However, government investment fell from 4.6% to 2.4% of GDP, and non-residential structures fell from 6.1% to 4.7% of GDP (Figure 6.3). Equipment investment only fell from 6.2% to 6.1% of GDP.

There have been fluctuations over time in the importance of these various categories—especially in residential and non-residential structures. Residential investment (Figure 6.2) has gone through several long cycles, peaking in the mid-70s and again in the late 1980s. It suffered a long recession during the early 1980s and a similar fate in the 1990s.

Housing does not directly contribute to estimates of productivity growth in the business sector because investment in housing, unlike business investment, is not a vehicle for introducing new technologies into businesses. However, the decline in housing investments to GDP could have an effect on the amount of housing stock available to serve a growing population.

Inventory investment is also volatile. Substantial disinvestment (i.e., negative changes) in inventory occurred in each of the two recessions of the early 1980s and early 1990s. Inventory investment as a percentage of GDP has trended downward over time—averaging around 1% of GDP in the 1960s but less than a tenth of that in the 1990s. This decline in inventory investment relative to GDP is the result of improved inventory management techniques that have enabled businesses to reduce their inventory holding costs.

The consequence of the decline in government investment has been the subject of a considerable debate in academic circles, especially in the United States. Several studies have argued that declining rates of public capital investment precipitated the decline in U.S. productivity growth.[2] However, other studies, using somewhat different measures of public capital, have found its impact on various measures of economic activity to be quite small. Most of the discussions about the role of public investment have focused on highways and other state and local government investments. But state and local investment accounts for only a portion of the decline. More important has been the declining fraction of GDP devoted to national defence. During the 1970s, the federal government made substantial purchases of aircraft, ships and other defence equipment. Investment in national defence picked up again in the mid-1980s, but it has subsequently fallen again relative to GDP.

[2] See Harchaoui (1997) on the contribution of public capital to productivity growth of Canadian industries.

Figure 6.3 Gross investment by component, share of GDP (in current prices)

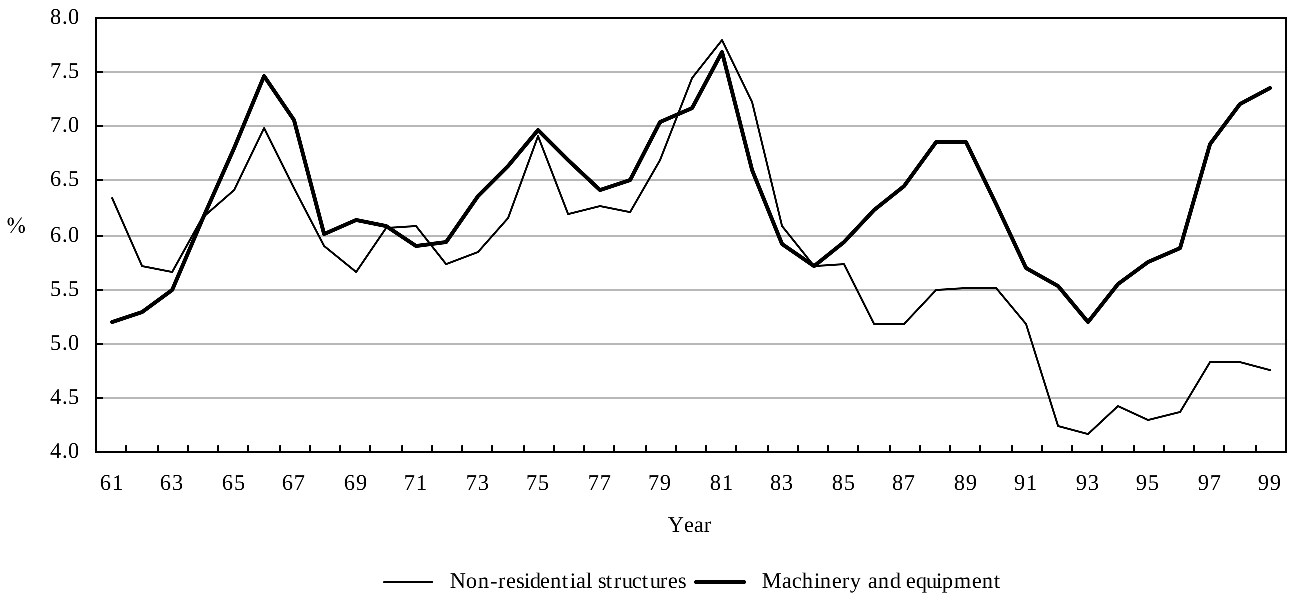
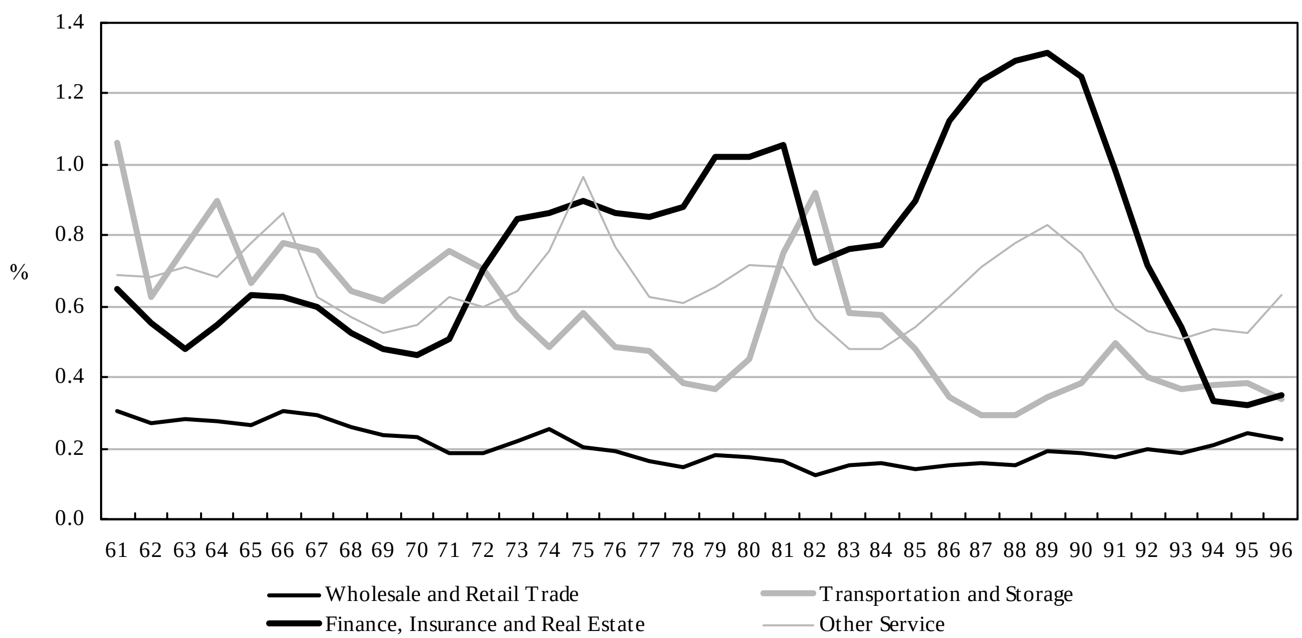


Figure 6.4 Gross investment in structures, selected industries, share of GDP (in current prices)



Regardless of their views on the decline in government investment, most advocates of higher savings and investment are concerned with business investment. The latter displays a highly variable pattern—with little long-run trend. The share of GDP going to business investment in equipment saw peaks in 1966, 1975, 1981 and 1989 (Figure 6.3). These peaks also broadly correspond to the cycles in non-residential structures. Recently, however, trends in these two components have diverged, with investment in structures trending downward while the share of GDP going to business equipment has begun to recover.

Pattern of the investment components

Investment in construction as well as machinery and equipment constitute the two components of business investment in Canada through which new technologies are introduced to the economy. Of these two, the non-residential structures component has fallen quite sharply as a percentage of GDP from comparatively high levels in the late 1970s.

This movement has been partially driven by a decline in commercial office construction, mainly in the finance, insurance and real estate sector.[3] From an average of 0.79% of GDP in the 1970s, this component increased to 1.0% in the 1980s and then declined to 0.63% in the 1990s. Vacancy rates soared in the early 1980s and 1990s, precipitating a commercial real estate ‘bust’ and a sharp curtailment in office construction (Figure 6.4).

Investment in mining construction (Figure 6.5) has also followed a pronounced ‘boom and bust’ pattern. Investment surged following the second oil price shock in 1979, increasing from 1.5% in the 1970s to over 1.9% of GDP in the 1980s. It then plummeted to 1.4% in the 1990s when real energy prices continued to decrease.

Energy-related utility investments (Figure 6.5) have also fallen to annual rates (0.77% in the 1990s) that are only half those in the 1970s (1.4%). This shrinkage in energy-related investment has occurred in the context of a decline in the real price of energy and a slowing in the growth of energy use.

Investment in railroad construction and other transportation infrastructures (relative to GDP) has fallen (Figure 6.4). In the 1960s, transportation investment was 0.8% of GDP while in the 1990s, it was only 0.4%.

Business machinery and equipment, the largest of the major components of investment, follows a different trend than the structures that are associated with the expansion of businesses. The fraction of GDP devoted to business equipment (Figure 6.3) rose on average from 6.2% in the 1960s to 6.5% in the 1970s and 1980s and then declined marginally to 6.1% in the 1990s.

While there has been a general absence of a trend for all components of machinery and equipment, it nevertheless has followed a highly cyclical pattern over the whole period.

The bulge in business equipment investment in the late 1970s reflected a confluence of forces—a cyclical peak that arose from a rising trend for investment in machinery and equipment, particularly agricultural machinery and oil field equipment, in response to rapidly rising food and energy prices.

The recession of the early 1980s produced a sharp fall-off in the more cyclical components of investment in manufacturing industries such as electrical, electronic and communication equipment, and motor vehicles, other transportation equipment and parts (Figures 6.6 and 6.7). At the same time, more moderate growth in agricultural prices created financial pressures for farmers, many of whom had expanded in the previous decade.

Investment in the machinery and equipment component, although hard hit by the recession of the early 1980s, slightly increased in the late 1980s (Figure 6.6). The recession of the 1990s brought business investment’s share of GDP to its lowest level for the 1961-1996 period. Since then, investment in business equipment has picked up and has exhibited the highest average annual growth rate of all past expansion periods (1966-1981 and 1982-1988). Nevertheless, as of 1996, business investment in machinery and equipment as a share of GDP remained below the highs reached in the early 1980s.

Turning to the industry distribution of machinery and equipment expenditures (Figures 6.8 and 6.9), several long-run structural changes are evident over the whole period. Other service industries, which include business services and communications, have expanded their share over most of the period (Figure 6.8). Although they experienced a distinct decline in share in the 1980s recession, they regained their 1970s share by the late 1980s and have more or less maintained it into the 1990s. Finance, insurance and real estate have also expanded their share over time, especially in the late 1980s and late 1990s. Wholesale and retail trade also expanded their share of investment.

[3] Even though this sector accounts for a modest 14% on average over the 1961-1996 period.

Figure 6.5 Gross investment in structures, selected industries, share of GDP (in current prices)

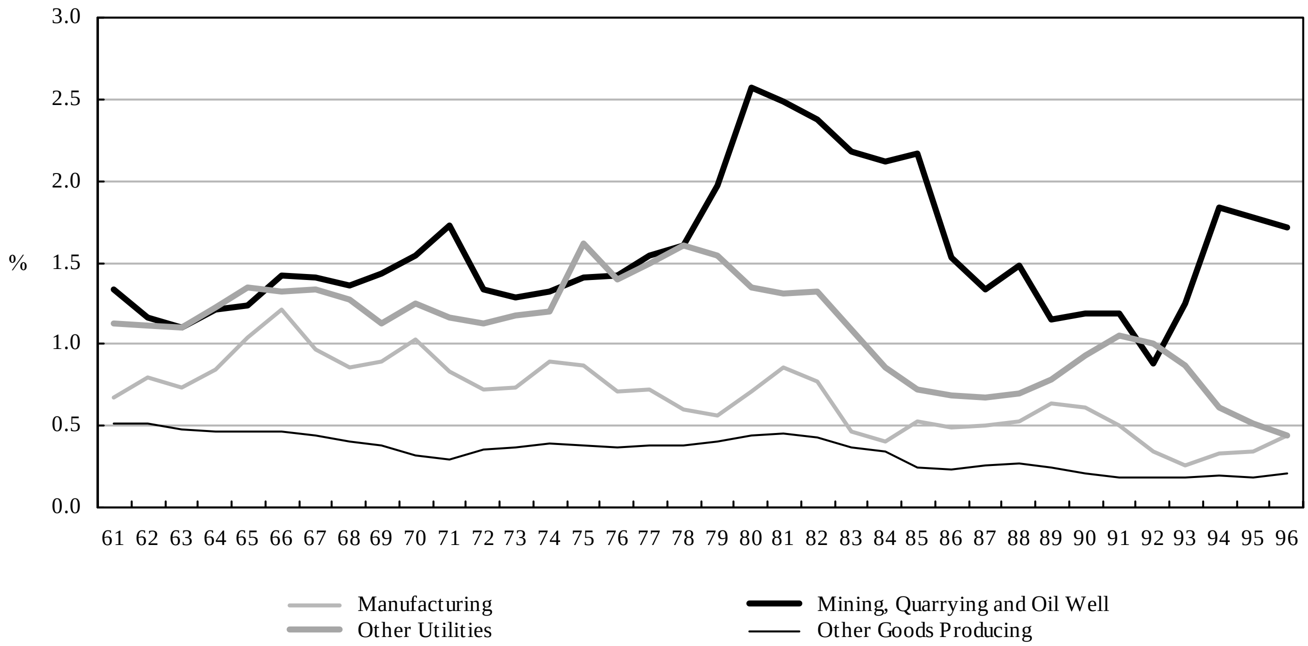


Figure 6.6 Gross investment in machinery and equipment by asset type, share of GDP (in current prices)

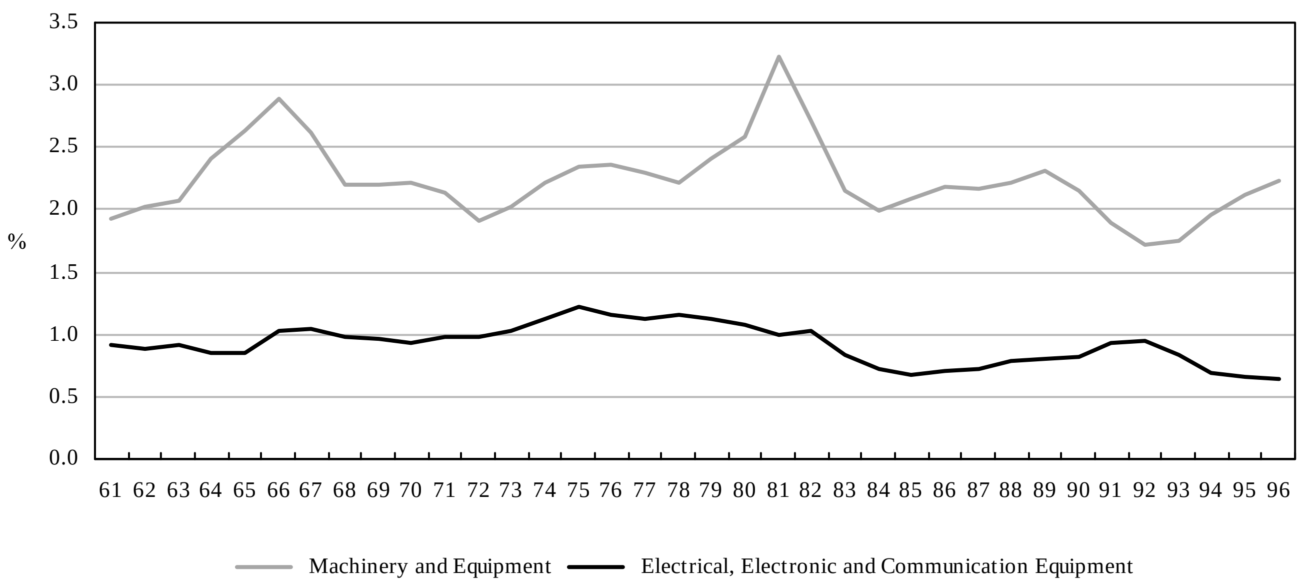


Figure 6.7 Gross investment in machinery and equipment by asset type, share of GDP (in current prices)

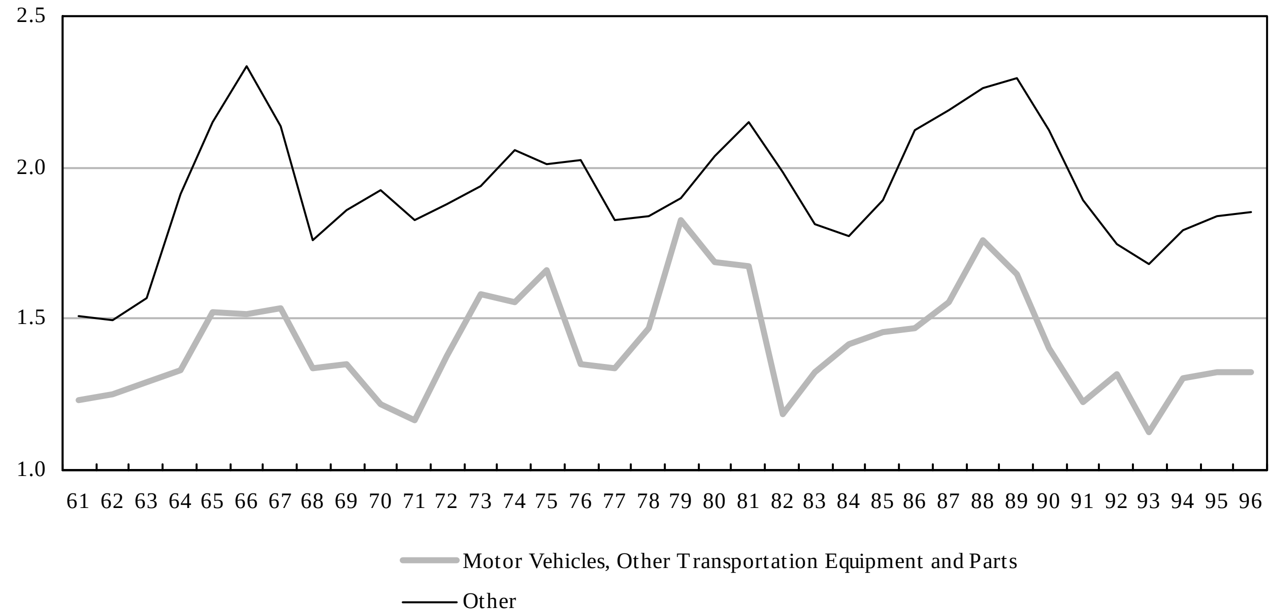


Figure 6.8 Gross investment in machinery and equipment, selected industries, share of GDP (current prices)

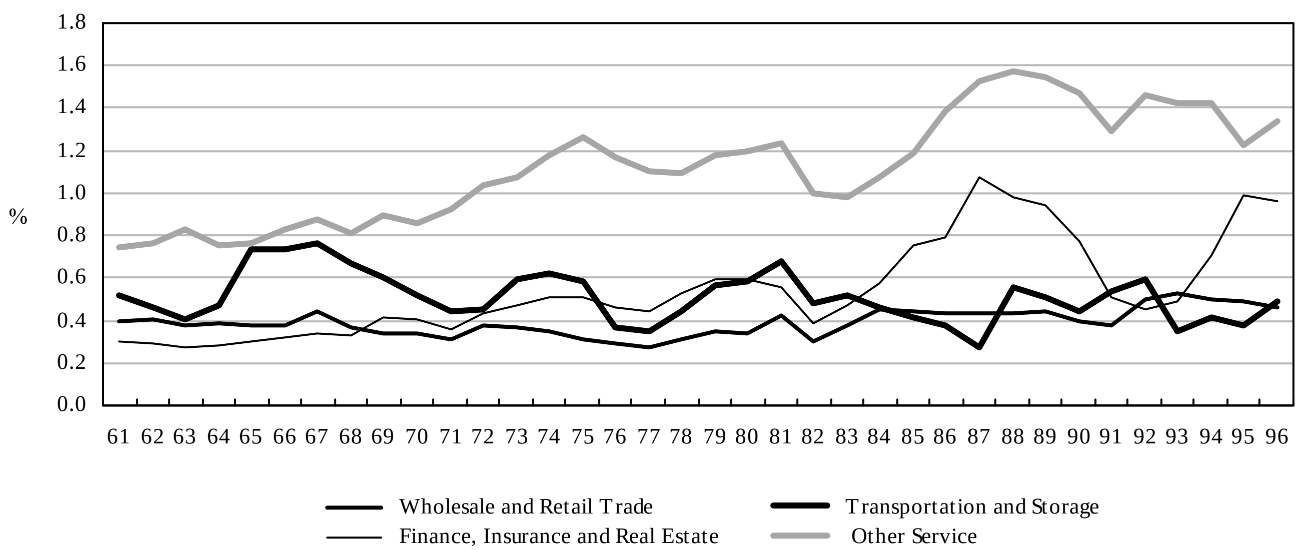


Figure 6.9 Gross investment in machinery and equipment, selected industries, share of GDP (current prices)

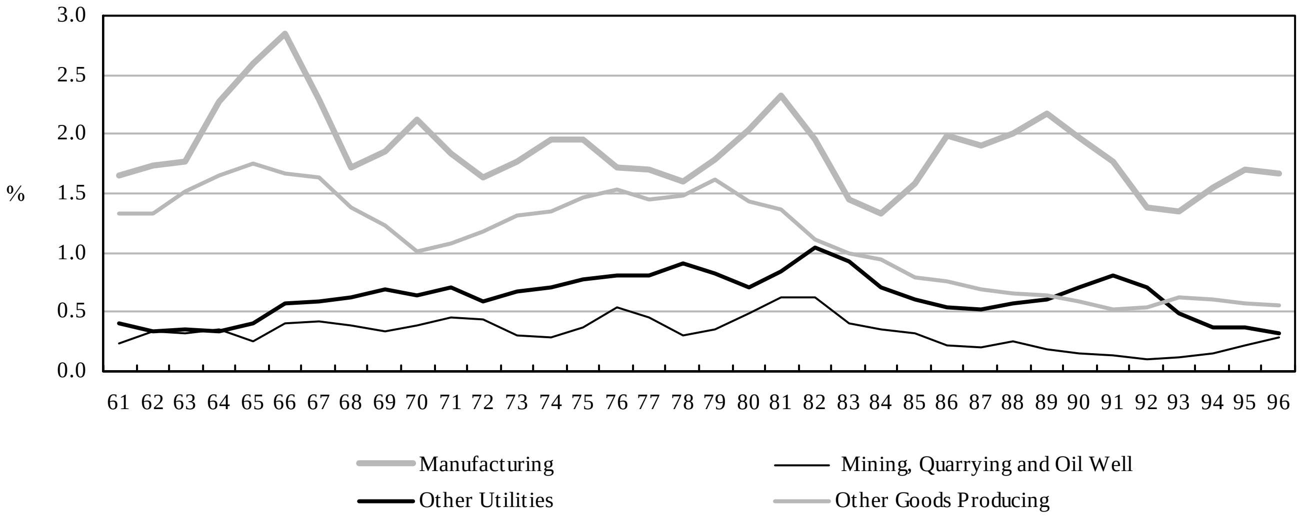


Figure 6.10 Gross investment, share of GDP, United States (in current prices)

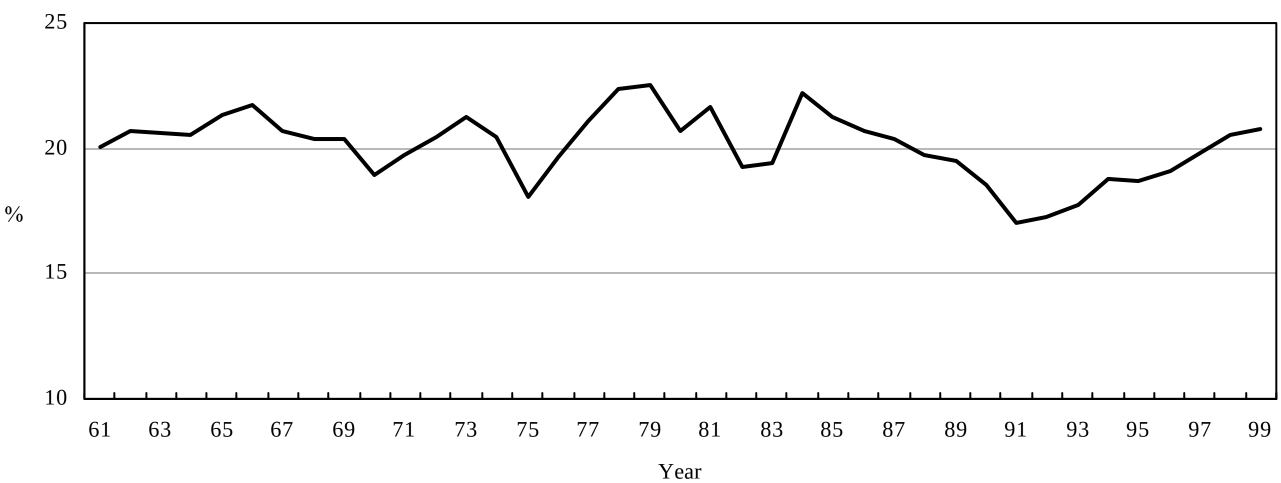


Table 6.1 Canadian and U.S. investment intensity, 1960-1999

	Canada	United States	Difference
		% investment divided by GDP	
Machinery and equipment			
1960–69	6.18	6.13	0.05
1970–79	6.45	7.18	–0.73
1980–89	6.54	7.78	–1.24
1990–99	6.13	8.20	–2.07
Residential structures			
1960–69	5.32	4.64	0.68
1970–79	6.37	4.94	1.43
1980–89	5.87	4.34	1.53
1990–99	5.28	3.88	1.40
Non-residential structures			
1960–69	6.14	3.71	2.43
1970–79	6.21	3.90	2.32
1980–89	6.13	4.35	1.78
1990–99	4.66	2.94	1.72
Government			
1960–69	4.59	5.21	–0.62
1970–79	3.58	3.71	–0.12
1980–89	2.82	3.63	–0.81
1990–99	2.45	3.33	–0.88
Total			
1960–69	22.22	19.68	2.54
1970–79	22.63	19.73	2.91
1980–89	21.37	20.09	1.28
1990–99	18.52	18.35	0.17

Note: The total includes only the following categories: residential; non-residential; machinery and equipment; and government. Inventories are excluded.

The utilities industry experienced an expansion phase in the 1970s and then a gradual decline afterwards. Transportation industries also followed much the same pattern, with an expansion in the late 1960s and early 1970s and then a gradual retrenchment thereafter.

The other goods industries (agriculture, forestry and fishing) decreased their share of investment. This decline was particularly marked after the 1980s recession, which was also the case for the mining industry.

Finally, manufacturing experienced a major investment boom in the late 1960s but then varied around a mean that did not change until the 1990s, when it declined slightly.

In summary, the historical pattern of investment in Canada indicates that the declining savings rate was primarily reflected in reductions in the share of GDP devoted to investment in non-residential structures and government. The proportion of GDP devoted to machinery and equipment remained roughly constant between the 1960s and the 1990s, with a peak in the early 1980s followed by a sharp drop back to previous levels. The record high of the ratio of investment in equipment to GDP experienced in the early 1980s coincided with transitory effects in the supply of agricultural products and oil. Oil-related investment alone accounted for half of the decline in business investment's share of GDP since the early 1980s. Similarly, a decline in investment in agricultural machinery also occurred when the rate of increase in agricultural prices slowed.

The Canadian experience in terms of the decline in the savings rate, its impact on investment rate, and the change in the composition of investment has both similarities and differences to the United States. Gross investment as a share of GDP in the United States has remained relatively constant over the past 20 years (Figure 6.10). Declines have occurred in residential structures and government investment in defence equipment but not in business capital expenditures in equipment (Figure 6.11). The change in the composition of U.S. business investment mirrors the Canadian experience. Cutbacks that have occurred in business investment in the United States have been concentrated in non-residential structures not equipment (Figure 6.12).

Figure 6.11 Components of gross investment, share of GDP, United States (in current prices)

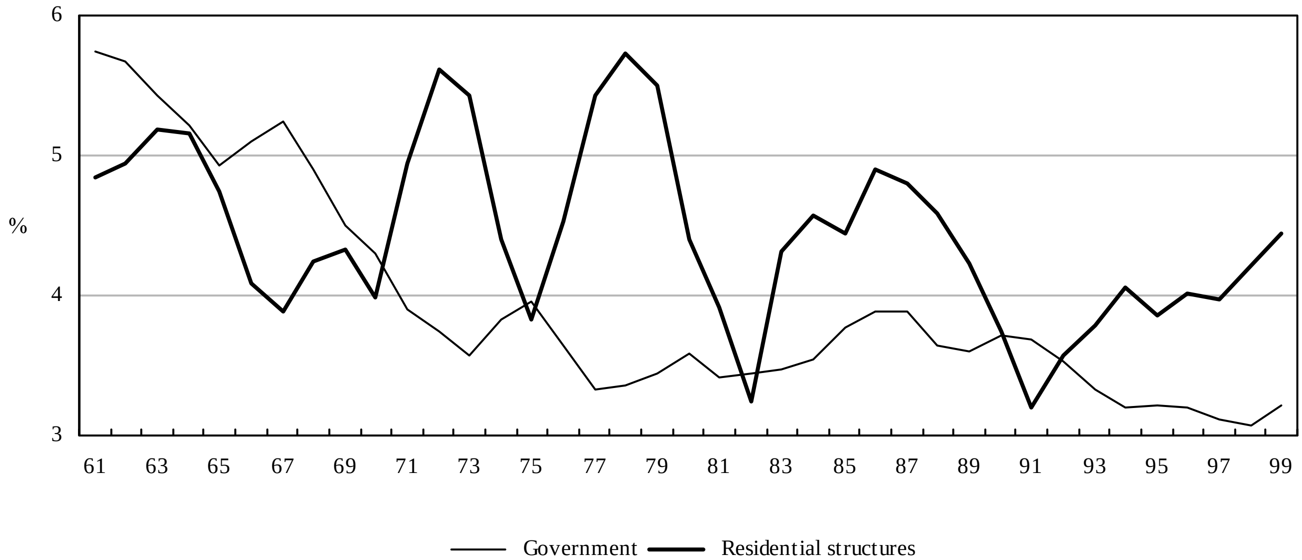


Figure 6.12 Components of gross investment, share of GDP, United States (in current prices)

Particularly pronounced were the reductions in spending on oil and gas exploration and development starting in the early 1980s and in expenditures on office buildings in the latter part of that decade. The sources explaining this drop are identical in both the United States and Canada—the collapse of oil prices and the high vacancy rates that emerged in many office markets.

The changes in investment intensity in Canada and the United States are compared in Table 6.1. Canada has consistently invested more (relative to GDP) than has the United States in residential housing. Since the 1970s, both countries decreased the proportion going to this area by about the same amount.

Canada has also spent more on structures, but the difference has been reduced. It was 2.4% in the 1960s, but only about 1.7% by the 1990s.

In contrast, the United States has consistently invested more in the government sector, but again both countries have reduced the amount spent relative to GDP by about the same amount.

A major difference between Canada and the United States occurs in machinery and equipment spending. The ratio of investment in machinery and equipment-to-GDP increased steadily in the United States from 6.1% of GDP in the 1960s to a record high of 8.2% in the 1990s. In contrast, the Canadian percentage of investment in machinery and equipment has remained relatively constant. By the 1990s, Canada was spending about 2 percentage points less of GDP on machinery and equipment than the United States.

In Canada, the fraction of GDP devoted to business equipment, which increased slightly between 1961 and 1999, has never significantly outperformed the contribution of residential and non-residential structures to GDP. The opposite is the case in the United States.

6.3 The financial structure of aggregate investment

In this section, we ask whether there have been changes in the patterns of financing that have accompanied shifts in the investment-to-GDP ratio. Changing patterns of financing may reveal that problems have arisen that have led to more expensive or less flexible sources of financing.

The corporate sector, which was responsible for 62% of investment in structures and equipment in 1997, financed its investment activities through a combination of funds generated internally and acquired from external sources.

The corporate sector can invest the funds that it raises in financial assets (investments in consumer or government debt) or non-financial assets (fixed investments such as plant and equipment). In other words,

Internal Funds + External Funds = Investments in Structures and Equipment + Inventories + Financial Assets

Funds generated internally consist of depreciation and undistributed profits (or profits less taxes and dividends). Of the two sources of internal funds, depreciation is by far the larger (69% over the 1961-1999 period).

Internal funds are much more important than funds raised from external sources. Figure 6.13 illustrates that corporations' funds generated internally, in the aggregate, generally approach their fixed investment expenditures. In the two recessions of the early 1980s and 1990s, funds generated internally fell very much short of fixed investments.

In the mid-1990s, funds generated internally moved back well above fixed investments. While individual corporations may make extensive use of external funds, the corporate sector's fixed investment expenditures can be said to be self-financing, since corporate savings in the form of undistributed profits and depreciation are roughly equal to corporate investment in plant and equipment.

At the same time as the corporate sector raises internal sources of financing, it also raises funds from external sources to finance investment in financial and non-financial assets. Financial assets consist of the obligations of others, such as foreign investments, credit granted to customers or government liabilities.

The reliance on external sources of financing has varied significantly since the early 1980s. In particular, use of credit markets (equity, corporate bonds, bank loans and mortgages) reached a high of 95% of fixed investment in 1981 and then dramatically declined to 15% in 1983. As one might expect, the corporate sector looked to markets more when funds generated internally did not keep pace with the growth in investment in the late 1970s and the late 1980s; and they curtailed their use of credit markets when internal funds rose relative to investment, as happened in the early 1980s.

The relative importance of the instruments used to raise external funds (credit market borrowing versus net equity issues) has varied considerably (Figure 6.14). During the early 1970s, when the corporate sector borrowed aggressively from credit markets to fund its investment programs, its reliance on the stock market was relatively low. The

Figure 6.13 Source of investment funds relative to fixed investment for non-financial corporations

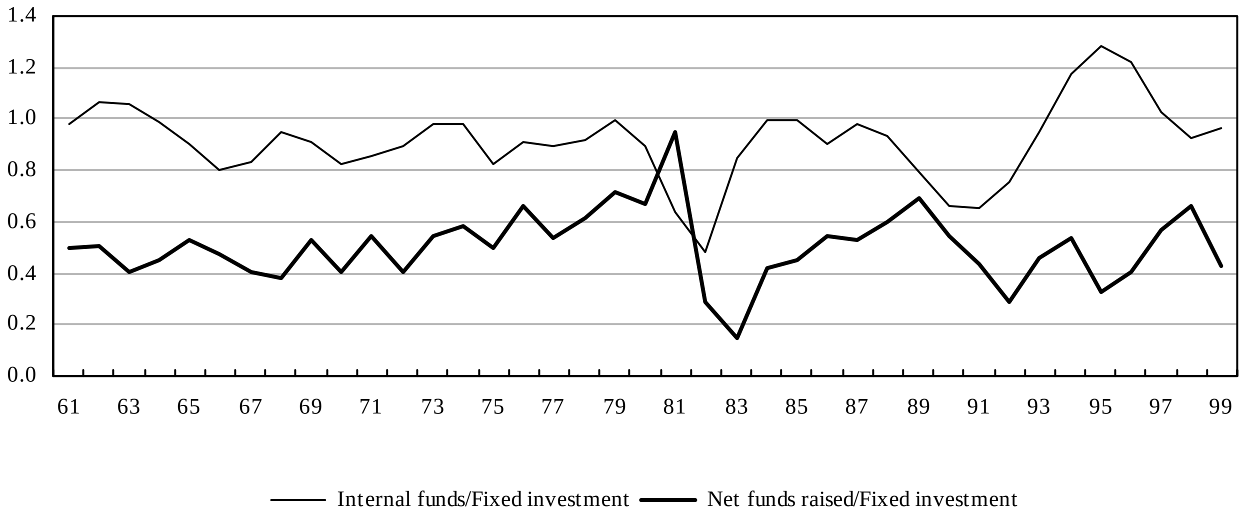
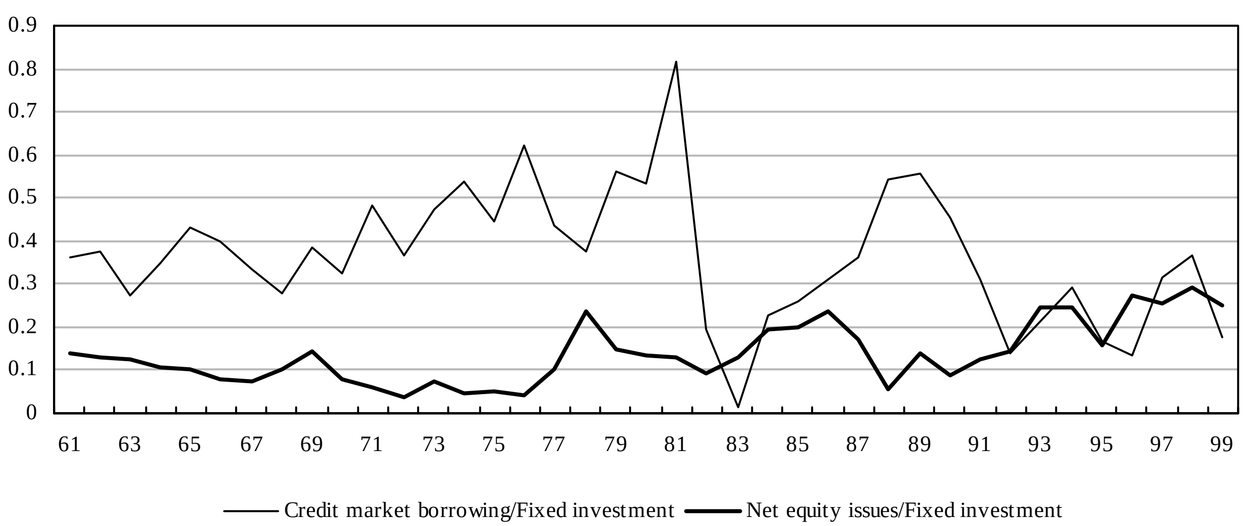


Figure 6.14 Source of investment funds relative to fixed investment for non-financial corporations



late 1980s was a time of increasing leverage, as corporations took on more debt while extinguishing equity through stock buybacks and mergers. In the recession of the early 1990s, borrowing from banks and other mortgage lenders declined while corporations continued to issue equities. During the recession, the equity and credit markets had about the same importance in financing investment. In the late 1990s, the corporate sector did not increase its use of credit markets, perhaps because of the record growth in internal funds.

Finally, we ask whether the changes in financing previously described led to dramatic shifts in the importance of each of the sources of funds to the business sector's balance sheets. For this we plot the ratio of retained earnings to equity as represented by net worth—the differences between assets and liabilities (Figure 6.15). If retained earnings had not kept up with total equity and enterprises had to resort more and more to equity markets, this ratio would have fallen over the period. Over the period 1965 to 1975—the period when the ratio of internal funds to fixed investment was relatively constant—the ratio of retained earnings to net worth fell, indicating a slight tendency to make more use of equity funds at this time. But over the period from 1976-1990, there is no trend in the ratio of retained earnings to net worth. It is not until the 1990s, when the amount of internal funds increased dramatically, that the balance sheet ratio of retained earnings to net worth began to increase.

To gauge the relative importance of debt, we plot the ratio of debt-to-total assets and debt-to-non-financial assets. The latter increased dramatically starting in 1975, thereby seeming to indicate that debt had become more important. However, the ratio of debt to total assets (which includes non-financial assets) remained constant. It appears that the increase in debt was used mainly to cover the increase in financial assets of the business sector—debt, as a ratio of total assets, remained constant.

6.4 Implications for capital-to-labour ratios

The preceding sections suggest that all components of business investment have not been constrained by the decline in savings. Investment in structures has declined, but investment in equipment has remained relatively constant as a proportion of GDP.

Ultimately, however, measures like labour productivity depend upon the capital stock per worker. The fact that investment as a percentage of GDP has remained relatively constant does not mean necessarily that capital per worker has increased. In this section, we examine the growth in capital per worker.

Investment has been sufficient to augment the capital-to-labour ratio, but the growth in this ratio after 1981 has been lower than in the period 1961-1981. Moreover, the rate of growth in the capital-to-labour ratio after 1991 has been essentially zero (Figure 6.16).

Separating trend from cyclical effects after 1981 is more difficult because of dramatic cyclical movements in the capital-to-labour ratio. Labour has displayed more variability during this period compared to previous periods. Nevertheless, whether we use peak-to-peak or trough-to-trough changes, the post-1981 picture is one of lower growth.

The movement in the aggregate capital-to-labour measure is affected by changes in the series of individual industries and of shifts in the relative importance of different industries.

In many industries, the capital-labour ratios have continued to rise since 1988 (Figures 6.17 to 6.19). Business services, fishing, retail trade, construction, finance, insurance and real estate, and communications grew in the latter part of the period.

However, in manufacturing, logging, accommodations, food and beverages, and mining and oil wells, the capital-to-labour ratios were relatively flat after 1988.

Two industries, transportation and agriculture, have declining capital-to-labour ratios. Transportation has been experiencing major restructuring, and agriculture has suffered a period of distressed prices.

Table 6.2 presents capital-to-labour ratios for all major industry groups for selected years, along with each industry's shares of labour and of the value of capital stock. The differences among industries are large. Some of the differences reflect patterns of ownership rather than use. In particular, the real estate industry owns buildings that are used by other industries. Many financial institutions also own buildings that are rented out to tenants in other industries. On the other hand, many service companies are retail outlets that rent space in buildings owned by others. In an attempt to remove the effects of these ownership patterns, a service sector is shown here that includes all of the wholesale and retail trade, finance, insurance, real estate and other service industries.

The trend in the overall capital-to-labour ratio reflects the joint effect of structural and technological changes. First, it is conceivable that technological changes associated with the new economy and the organizational changes to which it is giving rise require less capital than the systems they

Table 6.2 Effect of industrial shifts on the business sector capital-labour ratio

Industry	1966			1973			1979			1988			1997		
	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of capital (%)	Share of labour (%)[a]	Capital-labour ratio ($000)[b]	Share of Capital (%)	Share of Labour (%)[a]	Capital-Labour Ratio ($000)[b]
Agricultural and Related Services	6.5	10.9	10.3	5.0	7.9	13.3	5.7	6.9	19.2	3.2	5.3	15.7	2.0	4.7	12.2
Fishing and Trapping	0.3	0.5	10.0	0.2	0.4	10.8	0.2	0.5	9.0	0.1	0.6	4.3	0.1	0.3	8.1
Logging and Forestry	0.6	1.5	7.2	0.5	1.2	8.5	0.4	1.1	9.1	0.2	0.7	6.2	0.1	0.7	6.5
Mining, Quarrying and Oil Wells	8.4	1.8	79.5	10.1	1.7	122.2	9.7	1.8	127.0	10.6	1.6	168.0	8.9	1.6	164.9
Manufacturing	14.4	27.6	9.0	14.6	27.2	11.3	13.4	24.8	12.6	12.0	21.7	14.4	10.8	19.3	16.2
Construction	0.9	11.4	1.4	0.9	10.5	1.7	1.1	9.6	2.7	1.1	9.5	3.0	1.2	8.6	4.0
Transportation and Storage	12.8	6.5	34.1	11.0	5.8	39.9	8.8	5.9	34.6	7.4	5.2	37.1	6.7	5.7	33.9
Communication and Other Utilities	17.2	2.6	115.8	18.6	2.8	140.0	21.1	3.1	156.6	20.1	3.3	160.5	20.1	3.2	180.4
Service Sector	37.1	35.2	17.9	39.2	42.4	19.4	39.6	46.4	19.8	45.4	52.0	22.7	50.0	55.9	25.8
WholesaleTtrade	1.3	5.6	4.0	1.0	6.8	3.2	0.9	6.8	3.2	0.8	6.5	3.3	1.3	7.3	4.9
Retail Trade	2.6	12.8	3.4	2.0	13.9	3.1	1.8	14.0	3.1	1.6	14.9	2.9	2.1	14.6	4.1
Finance, Insurance and Real Estate	32.3	4.1	136.4	33.4	5.3	131.8	33.7	6.1	127.4	38.5	6.8	148.1	41.2	6.2	190.3
Business Services	0.1	2.3	0.5	0.1	3.6	0.5	0.1	4.9	0.6	0.3	6.8	1.1	1.0	9.7	3.0
Educational Services	0.1	0.1	22.3	0.1	0.1	17.2	0.1	0.1	32.4	0.1	0.1	30.9	0.2	0.2	34.4
Health and Social Services	0.3	0.9	4.9	0.3	1.4	5.1	0.4	1.6	5.2	0.4	2.6	3.8	0.4	3.5	3.6
Accommodation, Food and Beverage Services	0.6	5.1	2.1	0.8	5.4	3.0	1.1	6.6	3.7	1.5	7.8	4.8	1.4	7.0	5.9

Notes: [a] Labour is measured in terms of hours worked;

[b] Capital stock is measured in 1992 prices and is taken as the truncated geometric estimate.

Figure 6.15 Financial structure ratios of the Canadian business sector

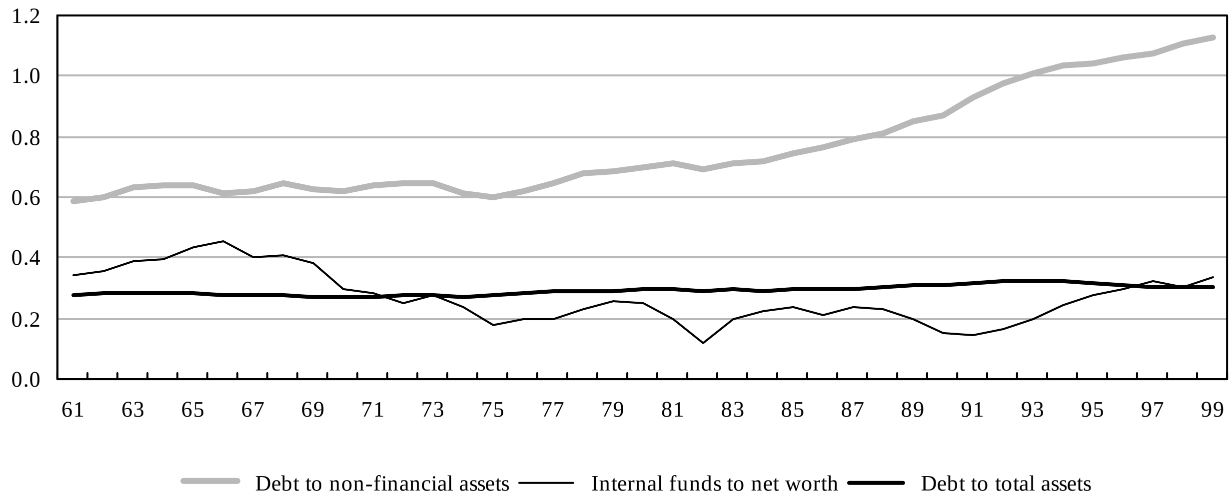


Figure 6.16 Capital-to-labour ratio for the Canadian business sector (1992 prices)

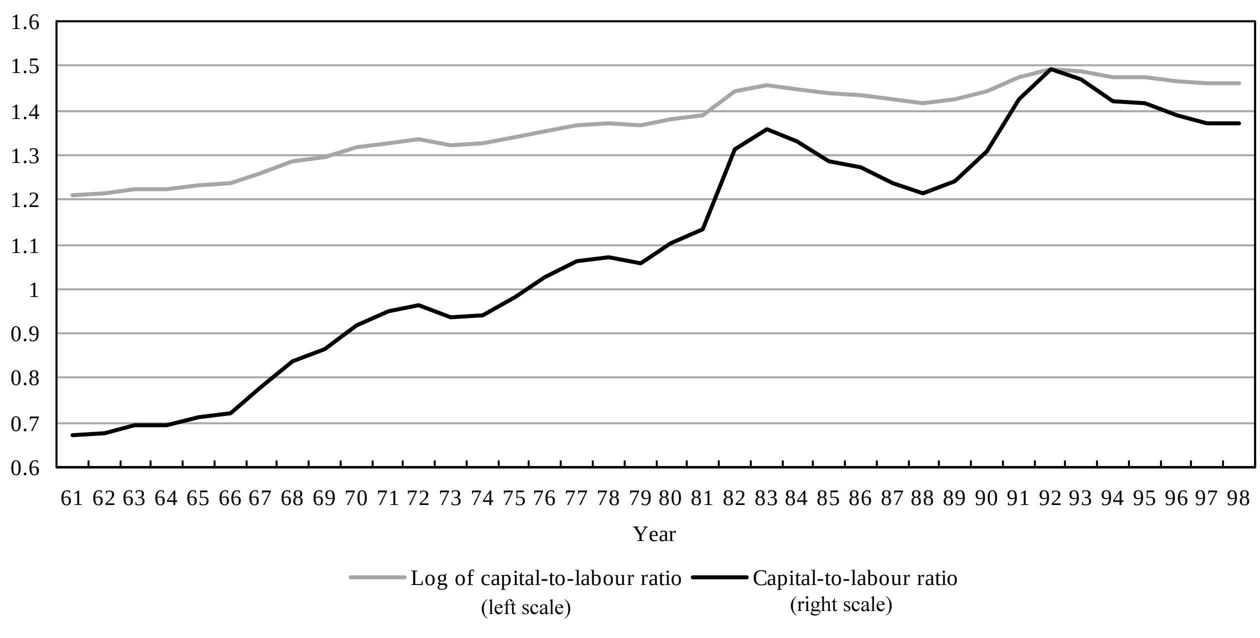
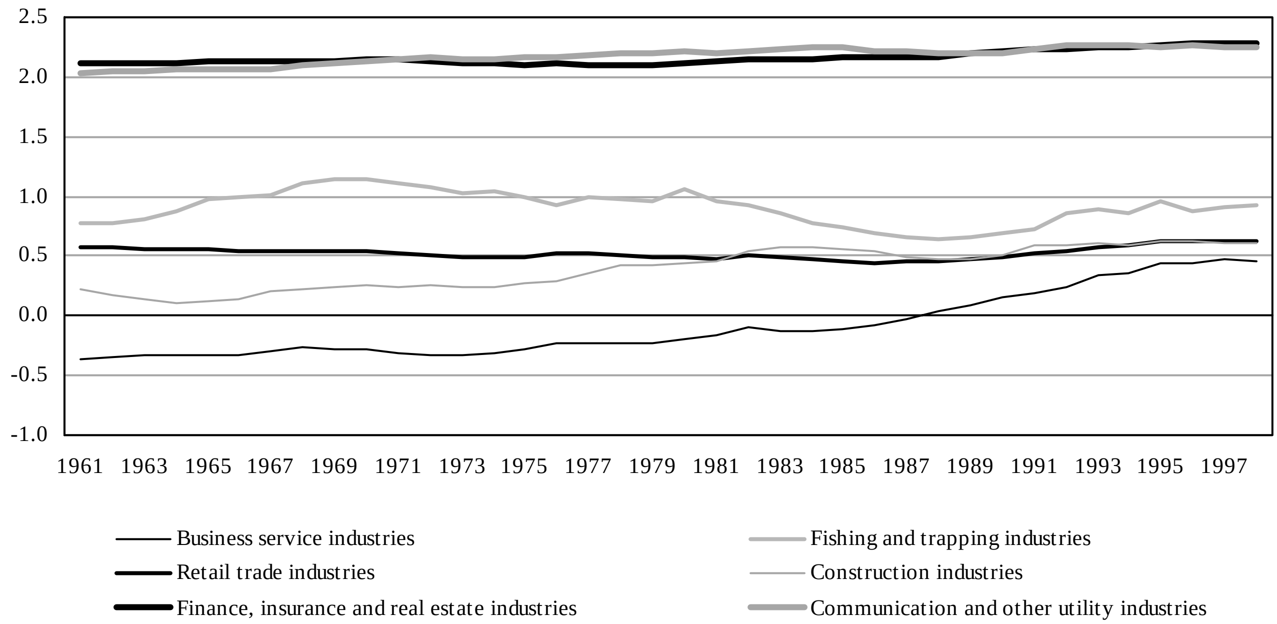
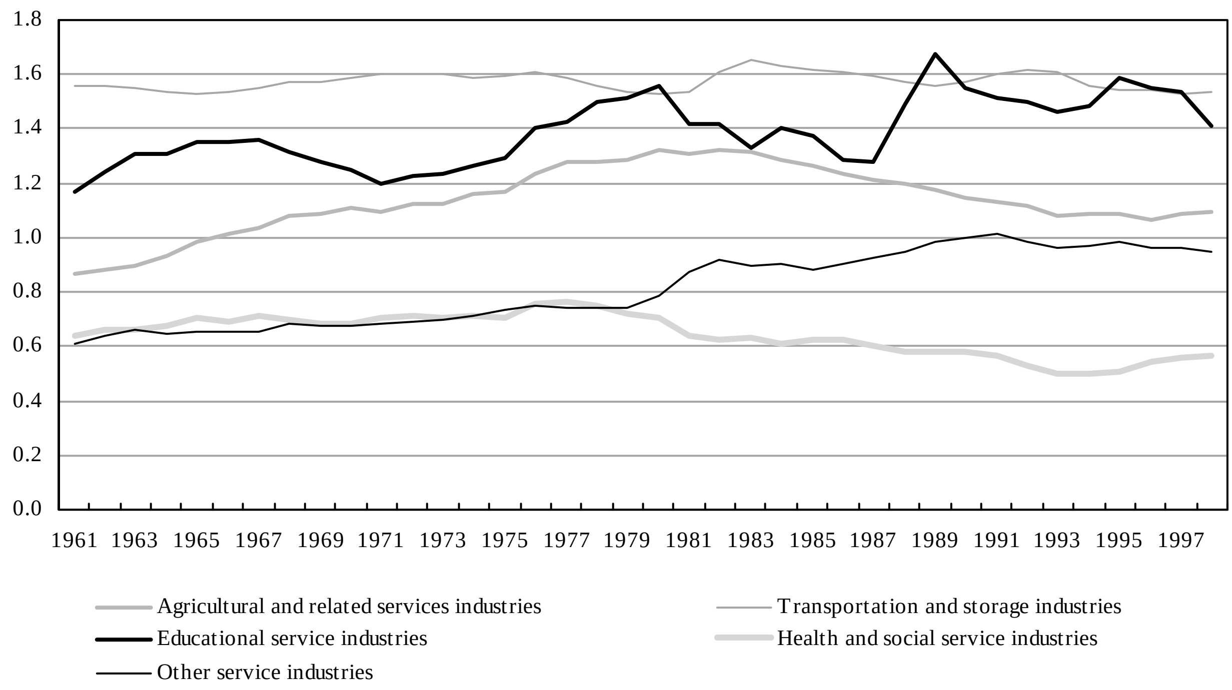


Figure 6.17 Capital-to-labour ratio, selected industries, Canada (1992 prices)[1]



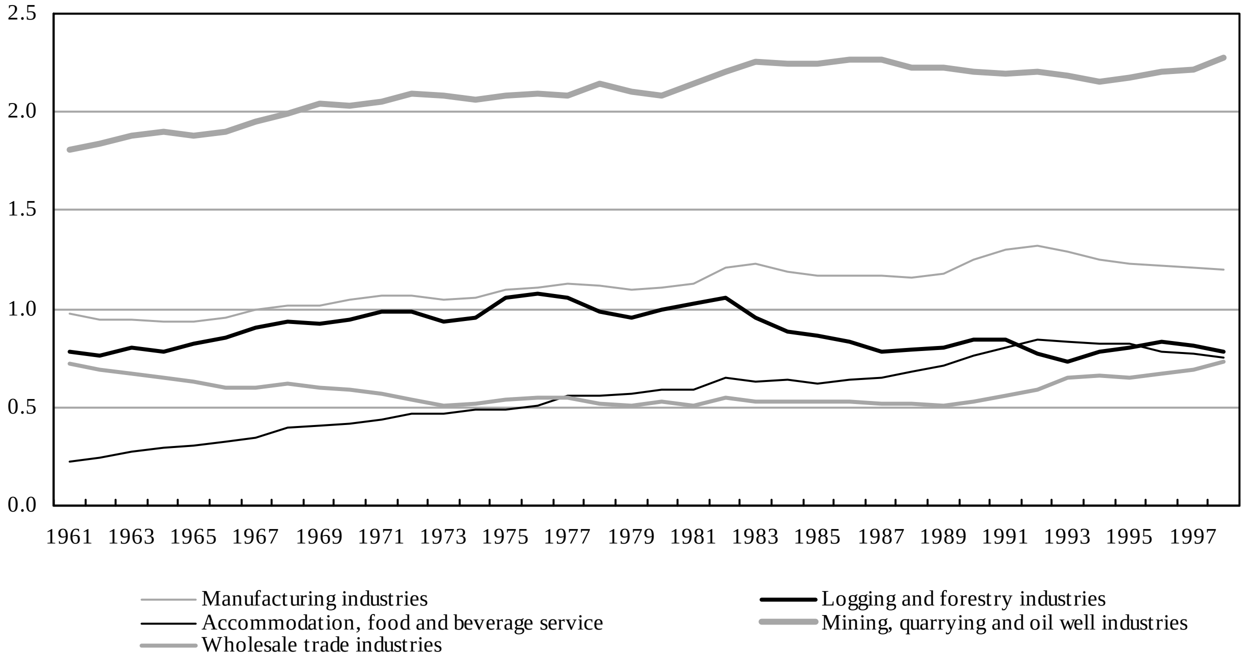
Note: 1. In logarithms.

Figure 6.18 Capital-to-labour ratio, selected industries, Canada (1992 prices)[1]



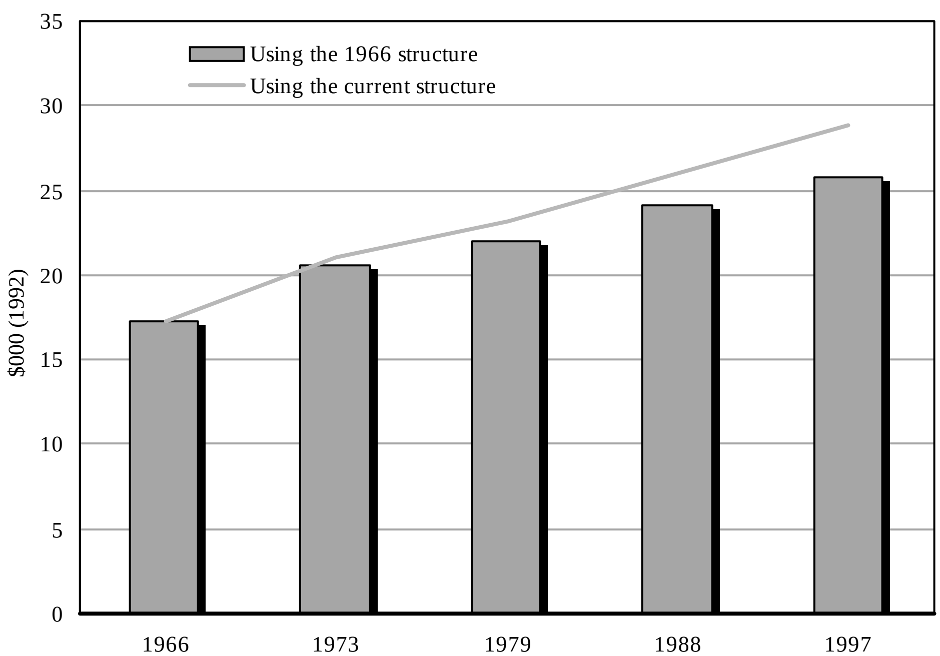
Note: 1. In logarithms.

Figure 6.19 Capital-to-labour ratio, selected industries, Canada (1992 prices)[1]



Note 1: In logarithms.

Figure 6.20 Capital-to-output ratio of the Canadian business sector, selected years



replace. There are instances where this appears to have occurred. Automated teller machines reduce the need for neighbourhood bank branches. The adoption of just-in-time inventory techniques reduces the need for warehouse capacity.

At the same time as these technological changes were occurring, structural shifts have resulted in the growth of some sectors at the expense of others. We perform a simple exercise to isolate the effects of structural change on the capital-to-labour ratio over the 1961-1997 period. We compare the actual increase in this ratio with the increase that would have occurred if all sectors had maintained their share of labour at the 1966 level.

Figure 6.20 depicts these two estimates of the business sector capital-to-labour ratios for 1966, 1973, 1979, 1988 and 1997, years that represent peaks of the business cycle. By using these years, we have attempted to provide estimates of the capital-to-labour ratio that are free of much of the influence of business cycles. The line is the observed capital-to-labour ratio and captures both structural and technological changes. The bars are derived by holding the labour shares constant at 1966 values and therefore captures only the effect of technological changes on the capital-labour ratio. Thus, the difference between the lines and the bar chart represents the net effect of structural changes on the capital-to-labour ratio.

From 1966 to 1997, the structural effect increased the capital-to-labour ratio by 18 percentage points, or 0.6% per year on average. Therefore, by holding constant the structure of the business sector, the capital-to-labour ratio would have grown at a slower pace. The bulk of this structural change is ascribed to growth in the services sector that experienced the largest increase in terms of size—more than 10 percentage points. Using the 1966 structure of the business sector attributes less importance to a sector whose capital-to-output ratio was larger than average and that grew at a rapid pace. In conclusion, structural shifts enhanced the aggregate capital-to-labour ratio over the period.

The absolute, though not the relative, contribution that this structural change has diminished over time. For the period 1966-1979, structural shifts accounted for about 5.1 out of the 34.7 percentage points of growth in the aggregate capital-to-labour ratio. Over the period between 1979 and 1997, structural shifts accounted for 3.5 out of 24.5 percentage points growth in the capital-to-labour ratio.

In summary, capital-to-labour ratios have been higher in the services sector than the average for all sectors. Thus, the rapid growth in the services sector, from 46% in 1979 to 56% in 1997 of hours worked, pulled up the overall ratio of capital-to-labour in the economy as a whole.

6.5 Conclusion

Investment spending has long been among the most closely watched elements of the national product accounts. During the past decade, the relative importance of investment in terms of output and the composition of investment in Canada changed dramatically. Workplaces were transformed as a result of investments in information processing equipment, such as computers, fax machines, copiers, and sophisticated telephones. Businesses have been purchasing more equipment than new office towers, shopping malls or other industrial facilities.

This chapter examines the pattern of investment in Canada and its composition across industries and assets since the early 1960s.

The chapter shows that while the savings rate dropped significantly over the last two decades, business investment has not borne the brunt of the lower savings rate. Declines in housing and government investment have cushioned the impact on business capital expenditures. The major drop in investment is caused by the drop in investment in structures; investment in machinery and equipment still remains high by historical standards.

In many respects, Canadian performance paralleled that of the United States. In both countries, the reduction in government investment, and non-residential structures bore most of the brunt of the investment slowdown. However there is one major difference. In the United States, investment in machinery and equipment increased as a share of GDP in the 1980s and 1990s, while in Canada, it remained relatively constant.

The chapter also asks whether changes in investment have been accompanied by changes in the sources of funds used to finance investment. The major drop in the business investment-to-GDP ratio in the early 1990s did not correspond to a relative decline in the funds that finance most business investment—funds generated internally. For most of the historical period, the corporate sector as a whole was self-financing; that is, funds generated internally more than covered fixed investments. Moreover, in the 1990s, this source actually exceeded fixed investments by a wide margin.

Finally, the chapter asks whether the changing investment intensity affected the amount of capital that is provided for the average worker. We find that the reduction in investment relative to GDP was accompanied by a slowdown in the growth of capital per worker. But the slowdown was not exacerbated by structural shifts away from goods industries towards services.

References

Bosworth, B.P. 1990. "International Differences in Saving." *American Economic Review.* 80,2: 377-381.

Edwards, S. 1995. "Why are Saving Rates so Different Across Countries? An International Comparative Analysis." National Bureau of Economic Research Working Paper Series No. 5097. April.

Ehemann, Christian, Arnold J. Katz, and Brent Moulton. 2000. "How the Chain-Additivity Issue is treated in the U.S. Economic Accounts," Bureau of Economic Analysis, U.S. Department of Commerce. OECD STD/NA(2000)25. Statistics Directorate. Paris. OECD.

Harchaoui, T.M. 1997. "Le capital public au Canada: évolution historique et externalités." *Économétrie appliquée* (Numéro spécial de *l'Actualité économique*, Gouriéroux and Montmarquette (eds)). 73: 395-421.

Statistics Canada. 1998. *National Economic and Financial Accounts, 1961-1992*. Quarterly Estimates. Catalogue no. 13-001-XPB.

Whelan, K. 2000. "A Guide to the Use of Chain Aggregated NIPA Data," Board of Governors of the Federal Reserve System.

7 The Cyclical Behaviour of Industrial Labour Productivity in Canada

JOHN R. BALDWIN AND TAREK M. HARCHAOUI

7.1 Introduction

Productivity is procyclical. That is, whether measured as labour productivity or total factor productivity, productivity rises in booms and falls in recessions. The recent macroeconomic literature views this stylized fact as an essential feature of business cycles. Economists have long regarded the long-run labour productivity growth rate as being important for growth and well-being. Procyclical productivity, by contrast, has received less attention in the business-cycle literature. In the last two decades, fluctuations in productivity have taken centre stage in modelling output fluctuations and are now viewed as an essential part of the cycle.

This chapter investigates changes in the cyclical behaviour of labour productivity over time. Two of the most important characteristics that are examined here are the volatility and the persistence of short-run movements in the labour productivity of individual industries. Disaggregated industry data are used to analyse whether short-run fluctuations have become less extreme or erratic over time and whether the tendency of shocks to have a permanent or transitory effect has changed between the pre-1973 and post-1973 eras.

Another aspect of cyclical behaviour that is examined in the chapter is the correlation of short-run changes in the labour productivity series across industries (co-movements).[1] Does the productivity of various industries move together, as would be the case if sectoral shocks had large and rapid spillovers? Or do individual series move in different ways, as would be the case if isolated, industry-specific shocks were more important and there were few spillovers? Have there been changes in the relative importance of various types of shocks over time?

If individual industries respond to shocks in a similar way, this suggests that aggregate factors are important or that industry shocks have strong spillovers to other industries. If industries respond quite differently, this indicates that isolated industry-specific shocks explain most of the movement in the productivity of various industries. This aspect of short-run behaviour is clearly relevant to the question of whether there is in fact a business cycle, characterized by many individual series moving up and down in concert. The predominance of industry-specific shocks is consistent with the view that industries are shocked at different times and that linkages between industries are weak or occur with a substantial lag.

A related issue is the relative importance of technology shocks and demand shocks in causing short-run productivity fluctuations in the pre-1973 and post-1973 periods. The effects of demand shifts are arguably less long-lasting than the effects of technology changes. If so, a finding that movements in the individual series are quite temporary suggests that demand shocks are driving cyclical movements in productivity. On the other hand, a finding that movements in the individual series are very persistent could suggest that technology shocks predominate. Determining the source of shocks is important for deciding whether traditional sticky-price models or real business cycle models of fluctuations are more appropriate.

[1] To measure and analyse the changes in the volatility, persistence, and co-movement of short-run fluctuations in the industrial series of productivity estimates, we use simple summary statistics such as the standard deviation and the autocorrelations of the growth rates of labour productivity series at the industry level.

7.2 Volatility in industrial labour productivity

Of all changes in short-run behaviour that may have occurred over time, the one that has received the most attention is the possible change in the volatility of fluctuations.[2] Therefore, it is useful to examine whether the volatility of labour productivity has changed between the pre-1973 and post-1973 eras.[3] The standard deviation of log differences of the labour productivity of 37 industries, which shows the dispersion of the growth rates of a productivity series around its mean, provides a measure of the volatility of fluctuations in the various time periods.

Table 7.1 reports the standard deviations of each series for each period. The individual series within each time period have very different levels of volatility. For example, within the pre-1973 era, logging and forestry industries have a standard deviation that is almost twice that of printing, publishing and allied industries, but substantially smaller than that of textile products. These large differences in volatility suggest that individual industries are either subject to quite different shocks or respond very differently to common shocks.

A much more important finding is that there has been a significant change in the standard deviation of the growth rates of various productivity series between the pre-1973 and the post-1973 periods. A convenient way to examine how much volatility has changed over time is to examine the ratio of the post-1973 standard deviation to the pre-1973 standard deviation of each series. These volatility ratios are given in Table 7.1.

Figure 7.1 shows a histogram of these ratios for the 37 industries. The median volatility ratio is 1.31 and the mean is 1.26. The volatility ratios for most of the industries are well above 1. For the total sample, 65% of the industries have ratios higher than 1, and half have a ratio higher than 1.25. This higher post-1973 volatility is particularly noticeable for five industries that are commonly considered among the most important industries in the Canadian economy. As a percentage of the total economy GDP in current prices for the 1961-1996 period, construction accounted for 9.2%, retail trade for 7.5%, wholesale trade for 4.9% and transportation for 4%. These four industries, which altogether represent almost one-third of the economy, have volatility ratios higher than 1, thus suggesting an economy that has become more volatile.

The volatility ratios reveal differences in the amount of stabilization shown by industries across sectors. The volatility ratios of the primary sector's industries are almost evenly distributed over the range 0.7 to 1.6. This indicates that there is a substantial amount of variation in the behaviour of the primary sector's productivity. Indeed, about as many primary industries have become more volatile as have become less volatile over time. For the manufacturing sector, the volatility ratios are clustered in the range 0.7 to 1.9. A majority of manufacturing industries have shown a substantial increase in volatility between the pre-1973 and post-1973 eras. The non-financial services industries show the greatest tendency to become more volatile. Some 63% of the industries have volatility ratios higher than 1.26.

The fact that there has been an increase in the volatility of most individual productivity series between the pre- and post-1973 era suggests that there has been a consistent increase in the combined effect of the shocks experienced by the 37 industries and the reaction to these shocks.

7.3 Persistence in industrial labour productivity

The measure of dispersion represented by the variance of a series, provides only one measure its volatility. It captures the amplitude of the variation over time in a series. Other characteristics of interest are the length of time it takes a series to complete a cycle (its period) and its tendency to move in conjunction with other series (i.e., its co-movement, which will be discussed below). The last two characteristics allow us to investigate the issues of persistence and commonality. Are movements in the productivity of particular industries mostly permanent or mostly transitory, and has the persistence of increases in productivity series changed over time? Do productivity series of different industries move in step with one another? This information is useful for determining the nature of shocks and the appropriate model of short-term fluctuations for the pre-1973 and post-1973 eras.

The extent to which the effects of shocks persist over time has been the subject of extensive investigation over the past two decades. Following the seminal paper by Nelson

[2] See Altman (1992).

[3] This chapter uses a subset of the labour productivity series published by Statistics Canada at the M- level of aggregation. Out of the 39 industries for which labour productivity are published, we excluded personal and household service industries and other service industries. The remaining 37 industries used in this chapter are members of the following sectors: primary (industries 1-7), manufacturing (industries 8-29), non-financial industries (industries 30-37).

Table 7.1 Volatility ratios of the Canadian industrial labour productivity series, 1961-1996

	1961-1973 (1)	1973-1996 (2)	Column 2/Column 1 (3)
1. Agricultural and Related Service	0.127	0.085	0.673
2. Fishing and Trapping	0.099	0.145	1.459
3. Logging and Forestry	0.045	0.071	1.578
4. Mining	0.102	0.099	0.969
5. Crude Petroleum and Natural Gas	0.183	0.140	0.761
6. Quarry and Sand Pit	0.088	0.094	1.066
7. Service Industries Incidental to Mineral Extraction	0.098	0.065	0.665
8. Food	0.030	0.035	1.180
9. Beverage	0.059	0.047	0.796
10. Tobacco Products	0.076	0.087	1.135
11. Rubber Products	0.054	0.081	1.497
12. Plastic Products	0.064	0.047	0.735
13. Leather and Allied Products	0.029	0.047	1.590
14. Primary Textile	0.061	0.071	1.160
15. Textile Products	0.073	0.061	0.840
16. Clothing	0.029	0.050	1.753
17. Wood	0.051	0.063	1.241
18. Furniture and Fixture	0.045	0.073	1.601
19. Paper and Allied Products	0.037	0.071	1.908
20. Printing, Publishing and Allied	0.025	0.042	1.664
21. Primary Metal	0.045	0.069	1.536
22. Fabricated Metal Products	0.028	0.040	1.441
23. Machinery Industries (except Electrical Mach.)	0.032	0.055	1.714
24. Transportation Equipment	0.081	0.065	0.803
25. Electrical and Electronic Products	0.057	0.051	0.897
26. Non-metallic Mineral Products	0.054	0.052	0.965
27. Refined Petroleum and Coal Products	0.154	0.117	0.761
28. Chemical and Chemical Products	0.036	0.060	1.648
29. Other Manufacturing	0.041	0.053	1.313
30. Construction	0.052	0.072	1.377
31. Transportation	0.040	0.070	1.783
32. Pipeline Transport	0.117	0.043	0.367
33. Storage and Warehousing	0.085	0.068	0.802
34. Communication	0.025	0.040	1.582
35. Other Utility	0.041	0.054	1.326
36. Wholesale Trade	0.018	0.050	2.709
37. Retail Trade	0.025	0.052	2.070
Median	**0.052**	**0.063**	**1.313**

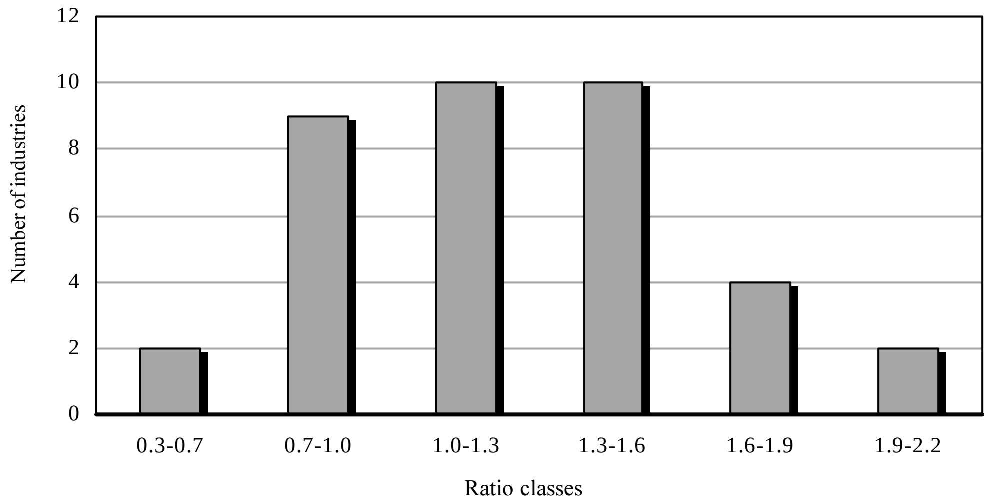
Note: The volatility ratios are calculated as the standard deviation of log differences of the labour productivity series of 37 industries within the 1961-1973 and 1973-1996 periods.

and Plosser (1982), aggregate output has been modelled by a first-difference stationary process, rather than by a stationary process around a deterministic trend. This has the important implication that macroeconomic shocks can have effects on output levels that continue into the indefinite future. An isolated recessionary shock may cause output growth to be temporarily lower than usual, but this would be reflected by a time path for the level of output that is permanently less than what it would have been in the absence of the shock.

The size of the long-run response of output to a unit shock, known as the persistence of shocks to output, is an empirical issue. Several studies have now been conducted to estimate the persistence measure for the real aggregate GDP. The evidence presented in these papers is mixed and inconclusive, largely reflecting the difficulties in determining the long-run properties of the aggregate output series (Pesaran et al. 1993).

In this section, we use the industrial labour productivity series in order to bring extra information to bear on the analysis of persistence at the aggregate level. A variance-ratio statistic is estimated with the same productivity series that were employed in the analysis of the volatility reported in section 7.2. A variance ratio is used to estimate the size of the random walk of the industrial productivity series.

Figure 7.1 Distribution of volatility ratios, 1961-1996



Cochrane (1988) has proposed the following variance-ratio (VR) estimate of the random-walk component:

$$VR(i,k) = \frac{Var\left(y_{t+k,i} - y_{t,i}\right)}{kVar\left(y_{t+1,i} - y_{t,i}\right)}. \qquad (1)$$

This estimate compares the variance of the k difference of individual labour productivity growth rate series $\left(y_{t,i}\right)$ from industry i to k times the variance of the first difference of labour productivity for the same industry. If a series follows a random walk, the variance of the industrial productivity increases proportionally with k (k is the difference horizon). Therefore the variance of $y_{t+k,i} - y_{t,i}$ will equal k times the variance of $y_{t+1,i} - y_{t,i}$. This variance ratio can be estimated non-parametrically and the estimates are robust to heteroscedasticity and non-normal random disturbances.

Persistence is measured by the limit of the variance ratio, VR. For example, $VR = 1$ for a series that follows a random walk whereas $VR = 0$ for any trend stationary series.

The non-parametric estimates of VR for $k = 5$ are given in Table 7.2.[4] These estimates indicate that there has been an increase in the persistence of short-term fluctuations between the pre-1973 and the post-1973 eras for many industries. The median of VR is 0.37 in the pre-1973 era and 0.63 in the post-1973 era. For the industries with highest output share, there is more evidence of a change of persistence over time. For example, the VR for construction increased from 0.50 in the pre-1973 era to 1.133 in the post-1973 era, and for crude petroleum and natural gas industries, it increased from 0.474 to 2.252. This finding indicates that the effects of shocks on the major industries have become more persistent over time.

The significant change in the amount of persistence shown by most industries between the pre-1973 and the post-1973 eras suggests that some combination of the nature of shocks facing industries and the reaction of these industries to shocks has changed dramatically over time. If shocks had changed, say, from being primarily transitory demand shocks in the pre-1973 era to being permanent supply shocks in the post-1973 era, one would expect to see a noticeable change in the persistence of fluctuations in the productivity estimates of most industries between the two periods. Following this reasoning, the dramatic increase in persistence shown by many industries tends to suggest that permanent shocks became more important in the post-1973 era or that the ability of these industries to recover from shocks slowed over time.

[4] While arbitrary, the value of five years seems a reasonable time period over which the properties of the changes in productivity are examined.

Table 7.2 Measure of persistence of the Canadian industrial labour productivity series, variance ratios by industry, 1961-1996

	Industry	1961-1973 (1)	1973-1996 (2)	Column 2/Column 1 (3)
1.	Agricultural and Related Service	0.272	0.200	0.735
2.	Fishing and Trapping	0.328	0.366	1.119
3.	Logging and Forestry	0.828	0.854	1.032
4.	Mining	0.033	0.736	22.566
5.	Crude Petroleum and Natural Gas	0.474	2.252	4.750
6.	Quarry and Sand Pit	0.642	0.771	1.201
7.	Service Industries Incidental to Mineral Extraction	0.139	0.316	2.275
8.	Food	0.318	0.343	1.078
9.	Beverage	0.389	1.205	3.101
10.	Tobacco Products	0.737	0.438	0.594
11.	Rubber Products	0.138	0.555	4.016
12.	Plastic Products	0.175	0.984	5.620
13.	Leather and Allied Products	0.370	0.669	1.808
14.	Primary Textiles	0.730	0.600	0.822
15.	Textile Products	0.225	0.587	2.613
16.	Clothing	0.656	0.528	0.805
17.	Wood	0.527	0.703	1.335
18.	Furniture and Fixture	0.281	0.378	1.342
19.	Paper and Allied Products	0.466	0.175	0.377
20.	Printing, Publishing and Allied	0.376	1.380	3.676
21.	Primary Metals	0.151	1.324	8.777
22.	Fabricated Metal Products	0.746	0.318	0.427
23.	Machinery Industries (except Electrical Mach.)	0.444	0.369	0.830
24.	Transportation Equipment	0.168	0.737	4.386
25.	Electrical and Electronic Products	0.263	0.414	1.579
26.	Non-metallic Mineral Products	0.545	0.687	1.261
27.	Refined Petroleum and Coal Products	0.499	0.747	1.498
28.	Chemical and Chemical Products	0.484	0.289	0.598
29.	Other Manufacturing	0.255	0.486	1.905
30.	Construction	0.500	1.133	2.264
31.	Transportation	0.384	0.550	1.430
32.	Pipeline Transport	0.328	1.632	4.979
33.	Storage and Warehousing	0.096	0.515	5.353
34.	Communication	0.334	0.852	2.552
35.	Other Utilities	0.667	0.964	1.445
36.	Wholesale Trade	0.341	0.839	2.458
37.	Retail Trade	0.200	0.625	3.125
	Median	**0.370**	**0.625**	**1.579**

Note: Estimates of persistence are based on the variance ratio (VR) proposed by Cochrane (1988). For example, $VR = 1$ for a series that follows a random walk (i.e., shocks have permanent effects), whereas $VR = 0$ for any trend stationary series (i.e., shocks have transitory effects).

In addition to examining possible changes in persistence over time at the industry level, it is also important to discuss the absolute level of persistence in the series of the various sectors before and after 1973. Do the estimates of VR suggest that fluctuations in the productivity series of particular sectors are mainly transitory or mainly permanent?

Table 7.2 shows that there is a noticeable difference in the level of persistence shown by the various sectors during the pre-1973 era. The median VR is roughly 0.33 for the primary sector, and 0.38 for the manufacturing sector. Not only are the estimates of VR moderately low for the majority of sectors but they are also not significantly different across major sectors. This clearly suggests that shocks tended to be transitory in the pre-1973 era and that sectors tended to behave similarly. The latter indicates that aggregate factors are important and affected each of the sectors in the same way or that sectoral shocks had weak spillovers to other sectors.

During the post-1973 era, shocks tended to be more persistent in comparison with the pre-1973 era for most sectors. The permanent effect of a shock is typically the longest for the non-financial services industry sector of the Canadian business sector. The estimates of VR for the primary sector indicate that a large fraction of the effects of a shock remains after several years, though shock effects are less persistent than if the productivity of this sector actually followed a pure random walk. The manufacturing sector experienced a moderately high median of the VR estimates. One interpretation of the persistence of fluctuations in the manufacturing sector is that shocks to this sector tend to come at least partially from the supply side, which, we have argued are particularly likely to be long lasting. However, it could also indicate that demand shocks have had longer lasting effects in the post-1973 period. The possibility that demand shocks have very persistent effects is particularly likely for industry-specific shocks if they are related to restructuring or to long-lasting disinflations associated with recessions in the early 1980s and 1990s.

It is noteworthy to mention that persistence and volatility are not related across industries. At the industry level, there is no significant correlation between the volatility of the growth rate and the persistence measure, either in the first or the second period. Moreover, the increase in the volatility is negatively correlated (though not significantly so) to the increase in the persistence measure. If we can say that a substantial portion of the increase in volatility is related to macroeconomic fluctuations, then the industries that have been most affected by macroeconomic fluctuations are not those where changes in productivity have been most persistent.

7.4 Co-movement in industrial labour productivity

The previous analysis has looked at the volatility and persistence of productivity estimates at the industry and sectoral levels. We investigated whether shock effects tended to be transitory or permanent and whether this tendency has changed over time. This section investigates whether the changes in industry productivity in one industry are closely related to changes in another industry. Ascertaining whether the productivity of individual industries moves in concert or separately is useful because it helps to identify which of the two types of behaviour are consistent with the observed pattern of short-run fluctuations in productivity.

The predominance of a common aggregate factor behind movements in productivity is consistent with models of productivity fluctuations in which all industries move together because of common aggregate demand or aggregate technology shocks. It is also consistent with models in which sectoral shocks have rapid and extensive spillovers to other sectors (Long and Plosser 1983; Murphy, Shleifer and Vishny 1989). The predominance of industry-specific shocks is consistent with the view that industries are shocked at different times and that linkages between sectors are weak or occur with a substantial lag (Lilien 1982).

In this section, factor analysis is used to analyse whether short-run fluctuations in labour productivity are related to the predominance of common aggregate shocks or industry-specific shocks. Additionally, we will investigate the issue of changes in the relative importance of these two types of shocks over the periods 1961-1973 and 1973-1996.

Factor analysis with one common factor is a statistical procedure that decomposes the movement in each member of a series into the part that is due to a single unobserved common factor and the part that is due to a disturbance unique to the individual series.[5] In terms of the notation given in previous sections, factor analysis decomposes the annual growth rate of each productivity series (y_{ti}) into the part that is due to a common disturbance (C_t) and the part that is due to a series specific disturbance (u_{ti}). That is

$$y_{ti} = \lambda_i C_t + u_{ti}, \tag{2}$$

where the variable C_t, derived from the cross-sectional pair-wise correlations between the productivity growth rates of labour productivity across industries, is used to capture the importance of a common aggregate disturbance. It is assumed that u_{it} and C_t are uncorrelated and that the series-specific disturbances are uncorrelated across industries.

The squares of the $\hat{\lambda}_i s$ provide estimates of the fraction of the variance of the growth rate of each series that can be explained by the unobserved common factor. In what follows, this fraction is interpreted as showing the relative importance of aggregate shocks in determining the behaviour of disaggregated productivity series in various time periods. However, it is important to note that the common movement in the series need not come solely from aggregate shocks such as changes in the money supply or the price of oil. Rather, it could come from sectoral shocks that spread rapidly from one industry to another.

[5] See Long and Plosser (1987) for an application of this technique.

The estimates of the $\hat{\lambda}_i s$ (the factor pattern) provide additional information on the signs of the responses of individual productivity series to the common factor: a series with a negative $\hat{\lambda}_i$ tends to move contrary to the common factor, while a series with a positive $\hat{\lambda}_i$ moves in the same direction. Changes in these signs between time periods indicate whether the series have changed in their relationship to the common factor and implicitly, therefore, in their relationship to one another.

Table 7.3 presents the factor patterns for the 37 industries in the pre-1973 and post-1973 periods. In both periods, the fraction of the total variation that is accounted for by the single common factor is low. Most change at the industry level is idiosyncratic.

The importance of the common factor varies substantially across industries. For some industries, the fraction of total variation accounted for by the aggregate factor is very low in both periods; for most others, the aggregate factor appears to account for at least half of the total variation only in the post-1973 period. The greater prevalence of industries for which the common factor is unimportant is illustrated by the fact that the median $\hat{\lambda}_i^2$ is 0.07 in the pre-1973 period and 0.24 in the post-1973 period. Since the $\hat{\lambda}_i s$ are derived from the sample cross-correlations, the finding that the $\hat{\lambda}_i^2 s$ of many industries are low is indicative of the fact that the cross-correlation between most industries is very small.

It is noteworthy that agriculture typically has a lower fraction of total variation explained by the common factor than do mining industries or most manufacturing industries. This is consistent with the notion that the agricultural sector is subject to its own common shock. The unimportance of the aggregate factor for agriculture also carries over to some manufacturing industries that are closely tied to agriculture, such as tobacco industries.

The industries for which the aggregate factor is most important are the largest mining and manufacturing industries, construction industries and transportation industries. In keeping with this pattern, the common factor explains much more of the total variance of oil and gas industries in the post-1973 period than in the pre-1973 period. The mining and manufacturing industries that do not appear to be affected by the common factor are typically minor industries, such as quarry and sand pits, non-metallic mineral products, leather and allied products.

How can one explain the fact that the aggregate common factor accounts for more of the variance of major industries than of minor industries? One possible explanation is that producers within major industries differ systematically from those operating in minor industries in a way that increases their sensitivity to aggregate disturbances. For example, major industries may be more capital intensive, or they may tend to be more heavily unionized than minor industries. Both of these differences could cause productivity in larger industries to respond particularly strongly to aggregate shocks such as changes in monetary or fiscal policy.

In addition to showing the importance of aggregate shocks within each era, the separate factor analyses for the two sample periods allow us to examine changes in the importance of the common factor over time. Table 7.3 shows that, between the pre-1973 and post-1973 periods, there has been a significant change in the fraction of a given subsector's total variance that is explained by the common factor. The median $\hat{\lambda}_i^2$ for all 37 industries in the post-1973 period is 0.24, up from 0.07. This increased importance of the common factor in the post-1973 period is consistent with the notion that large and powerful aggregate shocks affected the Canadian economy in recent years.

In the presence of such a large aggregate shock, even the behaviour of minor industries that are not particularly sensitive to aggregate disturbances would have been affected by the aggregate shock. There is also a consistent difference in the change shown by major and minor industries and across subsectors. During the post-1973 period, for mining industries, the fraction of the variance explained by the common factor is over 0.5 for all but one industry (quarries and sandpits). For manufacturing, the fraction is quite high for most industries. As a result, this aggregate effect might be expected to dominate the impact of industry-specific shocks.

In addition to providing evidence on the relative importance of the common factor, factor analysis also indicates the sign of the sensitivity of the individual series to the common factor. The estimates of the $\hat{\lambda}_i$ in Table 7.3 show that, in both periods, mining and manufacturing industries typically respond positively to the common factor. While there are a few exceptions to this pattern, none of the negative coefficients are large.

The fact that the size of the factor pattern has changed substantially over time provides important evidence that the relationship between the various industries has changed between the pre-1973 and the post-1973 periods. More

Table 7.3 Coefficient on the common factor in industrial labour productivity, 1961-1996

		1961-1973	1973-1996
1.	Agricultural and Related Service	-0.181	-0.133
2.	Fishing and Trapping	-0.084	-0.163
3.	Logging and Forestry	0.571	0.632
4.	Mining	0.452	0.752
5.	Crude Petroleum and Natural Gas	0.523	0.814
6.	Quarry and Sand Pit	0.324	0.441
7.	Service Industries Incidental to Mineral Extraction	0.145	0.712
8.	Food	0.293	0.746
9.	Beverage	0.348	0.623
10.	Tobacco Products	0.174	0.134
11.	Rubber Products	0.152	0.399
12.	Plastic Products	0.213	0.333
13.	Leather and Allied Products	0.185	0.237
14.	Primary Textiles	0.217	0.265
15.	Textile Products	0.253	0.316
16.	Clothing	0.322	0.397
17.	Wood	0.381	0.582
18.	Furniture and Fixture	0.222	0.281
19.	Paper and Allied Products	0.383	0.556
20.	Printing, Publishing and Allied	0.419	0.589
21.	Primary Metals	0.282	0.634
22.	Fabricated Metal Products	0.417	0.716
23.	Machinery Industries (except Electrical Mach.)	0.389	0.479
24.	Transportation Equipment	0.260	0.516
25.	Electrical and Electronic Products	0.154	0.084
26.	Non-metallic Mineral Products	0.195	0.136
27.	Refined Petroleum and Coal Products	0.543	0.667
28.	Chemical and Chemical Products	0.498	0.711
29.	Other Manufacturing	0.121	0.086
30.	Construction	0.488	0.689
31.	Transportation	0.485	0.767
32.	Pipeline Transport	0.117	0.332
33.	Storage and Warehousing	0.186	0.375
34.	Communication	-0.163	-0.066
35.	Other Utilities	0.079	0.134
36.	Wholesale Trade	0.317	0.486
37.	Retail Trade	0.186	0.541
	Median	**0.260**	**0.486**

Note: Estimates of the common factor $\hat{\lambda}_i$ are based on a statistical procedure that decomposes the movement of a series into the part that is due to a single unobserved common factor and the part that is due to a disturbance unique to the individual series. This procedure is known as factor analysis with one common factor. The u_{it} and C_t are assumed to be uncorrelated and the series-specific disturbances are uncorrelated across industries. The squares of the $\hat{\lambda}_i s$ provide estimates of the fraction of the variance of the growth rate of each series that can be explained by the unobserved common factor.

generally, the existence of a major change in the relationship between industries suggests that the structural changes that have occurred over time have altered the basic production relationships in the economy.

It should also be noted that the importance of the common factor is positively correlated with the persistence measure across industries. Industries that are more affected by common shocks are more likely to experience persistence effects from these shocks—especially in the earlier 1961-73 period. Moreover, in the manufacturing sector, though not elsewhere, the increase in the importance of the common effect over time is strongly related to the increase in persistence.

7.5 Conclusion

This chapter has used an annual productivity series of 37 industries to examine the volatility, persistence, and co-movement of fluctuations in labour productivity over the period 1961-1996. The main finding is that there has been a significant change in the short-run behaviour of individual productivity series between the pre-1973 and the post-1973 periods. Fluctuations in the productivity series of the majority of industries are larger in the post-1973 period than in the pre-1973 period. Similarly, the persistence of fluctuations and the importance of aggregate disturbances for most industries have substantially changed over time.

In addition to indicating changes in the behaviour of productivity over time, this chapter has provided additional evidence of cross-sectional variations in industry performance. For example, estimates of persistence show that fluctuations in the productivity of individual mining industries and manufacturing industries are quite long lasting, particularly in the post-1973 period, though some of the effects of shocks are undone eventually. The results of a simple factor analysis show that most of the variation in the productivity of minor industries is due to the industry-specific shocks, while much of the variation in major industries is due to a common factor.

It is important to ask whether all of the changes described herein—greater volatility, greater persistence, and a greater importance of common shocks—are related. At the industry level, the answer is that the relationships are weak. The industries that have the greatest increase in volatility are not those that experience the greatest increase in persistence. Indeed, the correlation between the increase in volatility and the increase in other two factors is negative. Volatility, which is probably closely related to demand shocks, then appears to be driven by forces different from those that cause persistence.

On the other hand, increases in persistence are positively related to the existence of a common factor, primarily in the manufacturing sector. It is possible to argue that the increases in persistence and the importance of a common factor could also arise from demand shocks that became more severe in the post-1973 period. However, the fact that increases in persistance and the common factor were unrelated to increases in volatility suggest they were related to supply shocks associated with changes in technology or restructuring.

References

Altman, M. 1992. "Business Cycle Volatility in Developed Market Economies, 1870-1986: Revisions and Conjectures." *Eastern Economic Journal.* 18: 259-275.

Cochrane, J.H. 1988. "How Big is the Random Walk?" *Journal of Political Economy.* 96: 893-920.

Lilien, D.M. 1982. "Sectoral Shifts and Cyclical Unemployment." *Journal of Political Economy.* 90: 777-793.

Long, J.B. and C.I. Plosser. 1983. "Real Business Cycles." *Journal of Political Economy.* 91: 39-69.

————. 1987. "Sectoral vs. Aggregate Shocks in the Business Cycle." *American Economic Review Papers and Proceedings.* 87: 333-36.

Murphy, K.M., A. Shleifer and R.W. Vishny. 1989. "Building Blocks of Market Clearing Business Cycle Models." *NBER Macroeconomic Annual. 4*: 247-287.

Nelson, C.R and C.I. Plosser. 1982. "Trends and Random Walks in Macro-economic Time Series." *Journal of Monetary Economics.* 10: 139-162.

Pesaran, M.H., R.G. Pierce, and K.C. Lee. 1993. "Persistence, Cointegration, and Aggregation: A Disaggregate Analysis of Output Fluctuations in the U.S. Economy." *Journal of Econometrics.* 56: 57-58.

8 Productivity Growth in the Canadian Manufacturing Sector: A Departure from the Standard Framework

John R. Baldwin, Valérie Gaudreault and Tarek M. Harchaoui

8.1 Introduction

Our interest in productivity growth arises from a desire to understand the process that generates economic growth.

The framework used to measure productivity growth decomposes output growth into two components. The first is the portion of output growth owing to increases in measurable inputs such as labour, materials, energy, services and capital. The remainder is caused by all other factors and is defined as productivity growth—or the growth in outputs that is not accounted for by the growth in inputs. It is a residual that measures all other factors contributing to output growth.

This residual can arise from a number of different sources. It can occur because firms have grown, possibly thanks to technological breakthroughs that allow them to exploit economies of scale. The residual can also arise from improved technologies that reduce costs for firms of all sizes.

Productivity growth measures produced by Statistics Canada and other statistical offices are based on an accounting framework that, for purposes of simplicity, assumes the instantaneous adjustment of inputs, no excess capacity, constant returns to scale, and perfect competition (i.e., price equals marginal costs). If one of these assumptions is violated, then the productivity residual will imperfectly measure the contribution of technological change to output growth.

Applied studies have suggested methods to estimate productivity growth that allow for scale economies (Denny, Fuss and Waverman 1981). They have also suggested methods to deal with problems that are caused by the fact that capital cannot be instantaneously adjusted, and that standard productivity estimates based on capital in place (rather than capital used) may contain biases (Berndt and Hesse 1985; Berndt and Fuss 1986).[1]

Bernstein and Mohnen (1991) and Morrison (1992) have developed an integrated econometric framework that makes adjustments in the standard estimates for scale economies, for imperfect input adjustments and for differences between prices and marginal costs. This is the framework that is adopted here and applied to detailed data on Canadian manufacturing industries over the 1961-1995 period.

[1] Hall (1988) and Domowitz, Hubbard and Petersen (1988) report significant markups of price over marginal cost in various manufacturing industries.

Statistics Canada's productivity estimates do not attempt to disentangle technological change from returns to scale. This chapter explores, in an experimental manner, the effect of relaxing the assumption that scale economies are not important.

The main purpose of this chapter is to measure the effect of modifying the standard productivity growth framework to remove the effects of scale economies. The chapter also investigates two other often-neglected areas.

First, it examines the validity of the assumption that markups—the deviation of price from marginal cost—are not important.

Second, it examines the effect of assuming that input markets adapt instantaneously. Most statistical offices assume that inputs are not marked by fixity. In reality, capital cannot be adjusted quickly. There are long periods over which capital is sometimes not fully utilized, when capacity utilization is less than 100%. While this problem has long been recognized, the solutions that have been chosen by statistical offices may not fully solve it.[2]

This chapter intends to decompose the standard estimate of productivity growth into two components: (1) that arising from scale economies and capacity fluctuations; and (2) the remaining residual. The latter has been referred to as the portion that really comes from technical progress as the 'true' productivity growth (Morrison 1992).

Our analysis begins in Section 8.2, where we outline the general framework taken from Morrison (1992) that accommodates the departure from the standard assumptions underlying the approach to productivity growth that underlies the estimates of most statistical agencies. Section 8.3 outlines the structural model used for empirical implementation and Section 8.4 presents the empirical results. The main conclusions of the chapter are summarized in Section 8.5.

Our principal findings indicate that the normal hypotheses used to estimate productivity—no markups, no fixity and constant returns to scale—are rejected. We also find that the assumption of constant returns to scale and full capacity tend to overestimate 'pure' technical change by roughly 30% over the period 1961 to 1995, but the estimate of this 'bias' is not very precise.

8.2 The analytical framework

8.2.1 The model and its role in assessing the issues

Productivity measures are meant to capture the increase in the efficiency of production over time. The concept of increasing efficiency can be formalized in either of two forms: (1) the growth in output when technology changes, holding the use of inputs fixed (the revenue or primal side); or (2) the diminution of costs for given levels of output and prices of inputs (the cost or dual side).

The primal approach measures productivity growth as the difference between output growth and input growth. The dual cost approach measures the difference between the rate of growth of unit cost and the rate of growth of the combined input prices—wage rates, energy and material costs.

[2] Because of the difficulty in precisely isolating the impacts of utilization on productivity, attempts to remove its effects often rely on calculating growth rates between cyclical peaks. This approach has drawbacks since identification of peaks can only be done after the fact.

If perfect competition, instantaneous adjustment (full capacity utilization) and constant returns to scale exist, $PY = C$ where Y is output, P is the corresponding price, and C is total costs, including only normal profits as a return on capital. This fundamental identity underlies the equivalency between output and cost-based measures of productivity. Therefore, when profits are zero, choosing the primal approach (focusing on the left-hand side of $PY = C$) is equivalent to the dual approach (focusing on the right-hand side of the expression).

To explain the theoretical linkages among productivity growth, scale economies, capacity utilization and markups, we describe the following in turn:

- how the primal and dual approaches to the measurement of productivity growth are related;
- how information on the relationship between costs and revenues should be incorporated into the cost and output shares used in the productivity growth computations; and
- how information on the returns to scale and the degree of capacity utilization can be combined within a unified framework to estimate a modified version of productivity growth that excludes their effects.

1) A general framework

a) Primal and dual non-parametric productivity frameworks

Consider the technology of firms to be characterized by a production function $Y = Y(X, t)$, or by a dual cost function $C = C(w, Y, t)$, where X is a vector of inputs, w is a corresponding vector of prices, and t denotes technical change. Then the elasticities of these functions with respect to t $\left(\varepsilon_{Yt} \equiv \frac{\partial \ell n Y}{\partial t} \text{ and } \varepsilon_{Ct} \equiv \frac{\partial \ell n C}{\partial t}\right)$ are referred to here respectively, as the primal and dual estimates of multifactor productivity growth. They reflect the residuals of total output (cost) growth less the contributions of the arguments of the functions other than t. The residual measure of technical progress—the growth in output that cannot be attributed to an increase in inputs or, conversely, the diminution of costs not explained by changes in input prices—has been denoted as the Solow residual (Solow 1958).

The traditional primal or output-side specification of multifactor productivity growth is written as

$$\begin{aligned} \varepsilon_{Yt} \equiv \frac{\partial \ell n Y}{\partial t} &= \frac{\left(\frac{dY}{dt}\right)}{Y} - \sum_{i=1}^{I} \frac{w_i X_i}{PY} \cdot \frac{\left(\frac{dX_i}{dt}\right)}{X_i} \\ &= \frac{\dot{Y}}{Y} - \sum_{i=1}^{I} s_i \frac{\dot{X}_i}{X_i}, \end{aligned} \qquad (1)$$

where the symbol '·' on each variable denotes a time derivative, and s_i is the share of input i in terms of the value of total output $\frac{w_i X_i}{PY}$.

With perfect competition, instantaneous adjustment and constant returns to scale, this is equivalent (except for a change in sign, so that $\varepsilon_{Ct} = -\varepsilon_{Yt}$) to the cost-side specification (Ohta 1975)

$$\varepsilon_{Ct} \equiv \frac{\partial \ell n C}{\partial t} = \frac{\left(\frac{dC}{dt}\right)}{C} - \frac{\left(\frac{dY}{dt}\right)}{Y} - \sum_{i=1}^{I} \frac{w_i X_i}{C} \cdot \frac{\left(\frac{dw_i}{dt}\right)}{w_i}$$
$$= \frac{\dot{C}}{C} - \frac{\dot{Y}}{Y} - \sum_{i=1}^{I} \omega_i \cdot \frac{\dot{w}_i}{w_i}, \qquad (2)$$

where ω_i is the share of input i in terms of the total cost $\frac{w_i X_i}{C}$.[3]

The equivalence between the two approaches occurs because of the assumptions that there are no returns associated with a) technological characteristics such as economies of scale, b) the variation in the utilization of inputs,[4] and c) market power, implying that $s_i = \omega_i$.

b) Implications for the fundamental accounting identity

If the assumptions of perfect competition, full capacity utilization, and constant returns to scale are invalid, differences between revenue and costs will occur. For example, this can arise because non-constant returns to scale or fixity cause $AC \neq MC$ (where $AC = \frac{C}{Y}$ and $MC = \frac{\partial C}{\partial Y}$ denote, respectively, average cost and marginal cost) or because imperfect competition implies $P \neq MC$.

The simple identity between revenues and costs can be written as:

$$PY = C \cdot \frac{MC \cdot Y}{C} \cdot \frac{P}{MC} = C \cdot \frac{\varepsilon_{CY}}{\left(1 + \varepsilon_{PY}\right)} = C \cdot ADJ, \qquad (3)$$

where ADJ is a factor that measures the extent to which revenue deviates from costs. This deviation arises from the fact that revenue—and therefore the revenue share appearing in (1)—embodies returns to all characteristics of the production process (including excesses of price over marginal revenue) that cause $PY \neq C$. However, costs C (and thus the cost shares) include only ex ante returns to inputs so (2) captures the effect of technical change independent of these other effects.

3 From the definition $C = \sum_i w_i X_i$, compute $\frac{\dot{C}}{C} = \sum_i \frac{w_i X_i}{C}\left(\frac{\dot{w}_i}{w_i} + \frac{\dot{X}_i}{X_i}\right)$. Substituting this result into the definition of the dual specification of multifactor productivity growth ε_{Ct} yields:
$\varepsilon_{Ct} = -\frac{\dot{Y}}{Y} + \sum_i \frac{w_i X_i}{C} \cdot \left(\frac{\dot{X}_i}{X_i}\right) = -\left(\frac{\dot{Y}}{Y} - \sum_i \frac{w_i X_i}{P_Y Y} \cdot \left(\frac{\dot{X}_i}{X_i}\right)\right) \equiv -\varepsilon_{Yt}.$

4 The value of marginal products of inputs just covers their hire cost, so full utilization is maintained.

This adjustment factor ADJ contains two elasticity expressions. The cost elasticity $\varepsilon_{CY} = \frac{\partial \ell n C}{\partial \ell n Y} = MC \cdot \frac{Y}{C}$ and the inverse demand elasticity $\varepsilon_{PY} = \frac{\partial P(Y,\Gamma)}{\partial Y} \cdot \frac{Y}{P}$, where $C = C(w,Y,t)$ and $P = P(Y,\Gamma)$, represent, respectively, the total cost function and the inverse demand function, and Γ is a vector of shift variables for the output demand function.

The equivalence of output and cost-based measures of productivity is destroyed when a firm either enjoys market power (for example, as a result of a factor such as product differentiation $\varepsilon_{PY} \neq 0$) or experiences non-constant returns (long-run fixities or short-run fixities) and, as a result, the scale estimate $\varepsilon_{CY} = \frac{MC}{AC}$ differs from 1 ($\varepsilon_{CY} \neq 1$).

Then the identity $PY = C$, upon which the equivalence of the primal and the dual approach depends, no longer holds. To re-establish the identity requires the use of the adjustment factor ADJ.

c) The relationship between scale economies and capacity utilization

Morrison (1985) has shown that the cost elasticity with regard to output can be divided into two components—an estimate of the long-run returns to scale, and capacity utilization:

$$\varepsilon_{CY} = \eta\left(1 - \varepsilon_{CK}\right) = \varepsilon_{CY}^{L} \cdot CU = \frac{MC \cdot Y}{C^*} \cdot \frac{C^*}{C}, \qquad (4)$$

with $C(w,Y,t) = G(w',Y,K,t) + w_K \cdot K,$ where $G(\cdot)$ is a variable cost function and K is the stock of capital, a quasi-fixed input, having an ex ante rental (market) price w_K, $\eta = \varepsilon_{CY}^{L} = \frac{MC \cdot Y}{C^*}$ is the inverse of long-run returns to scale and $CU\left(\equiv \frac{C^*}{C}\right)$ is the cost side measure of capacity utilization. The associated shadow cost function is defined $C^*(w,Y,t) = G(w',Y,K,t) + w_k \cdot K,$ where $z = -\frac{\partial G}{\partial K}$ is the shadow price of K.[5]

Combining (3) and (4) gives the following modification that needs to be made to the fundamental identity between revenues and costs in recognition of the existence of non-competitive behaviour, fixity and returns to scale:

$$PY = C \cdot \frac{MC \cdot Y}{C^*} \cdot \frac{C^*}{C} \cdot \frac{P}{MC} = C \cdot \frac{\varepsilon_{CY}^{L} \cdot CU}{\left(1 + \varepsilon_{PY}\right)} = C \cdot ADJ. \qquad (5)$$

Equation (5) indicates that the change in costs, as output varies, depends on the economies of scale parameter associated with the long-run average cost curve and the constraints of short-run input fixity that are reflected in the slope of the short-run curve (cost changes arising from potential returns to variable inputs in the short run). When

[5] $MC = \frac{\partial C}{\partial Y} = \frac{\partial G}{\partial Y}$ and $CU = \frac{C^*}{C} = 1 - \varepsilon_{CK}$, where $\varepsilon_{CK} = \frac{\partial C}{\partial K} \cdot \frac{K}{C} = \frac{(w_K + \frac{\partial G}{\partial K}) \cdot K}{C}$.

long-run constant returns to scale exist, $\varepsilon_{CY}^{L} = 1$, then all cost changes arising from output changes are associated with short-run returns to inputs. When instantaneous adjustment prevails, $\varepsilon_{CK} = 0$ and cost changes result only from movements along the long-run cost curve. This full equilibrium condition is equivalent to saying that $CU = 1$; capacity defined in terms of fixed inputs is fully utilized.

2) A simple framework to illustrate the problem

To explain the problems that arise from violations of the assumptions of constant returns to scale—full capacity and perfect competition—consider briefly the primal productivity estimate in the case where the production function can be characterized by a Cobb-Douglas functional form[6]

$$Y = K^{\alpha} L^{\beta} e^{\mu t}, \tag{6}$$

where Y is output, K is capital, L labour, t is an index of the state of the technology and α, β, μ are unknown parameters with $\alpha + \beta = 1$, which is required by the constant returns-to-scale assumption. The total derivative of (6) with respect to t yields

$$\begin{aligned} \frac{d\ell nY}{dt} &= \frac{\partial \ell nY}{\partial \ell nL} \cdot \frac{d\ell nL}{dt} + \frac{\partial \ell nY}{\partial \ell nK} \cdot \frac{d\ell nK}{dt} + \frac{\partial \ell nY}{\partial t} \\ \frac{\Delta Y}{Y} &= \alpha \frac{\Delta L}{L} + \beta \frac{\Delta K}{K} + \mu, \end{aligned} \tag{7}$$

where $\frac{\Delta Y}{Y}$ indicates the percentage change of Y (similarly for K and L). Recall that μ, which captures the shift of the production function (6), is identical to ε_{Yt} in (1). Therefore, rearranging (7), we now have multifactor productivity growth $\left(\mu \equiv \varepsilon_{Yt}\right)$:

$$\varepsilon_{Yt} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta L}{L} - \beta \frac{\Delta K}{K}. \tag{8}$$

To measure multifactor productivity growth, it is important to estimate the parameters α and β, since neither is directly observable. However, by assuming constant returns to scale (the total compensation of the inputs exhausts the total product: $PY = w_L + w_K$), perfect competition (the output price, which is identical to its marginal revenue, equals marginal cost: $P \equiv MR = MC$) and full capacity (the value of the marginal product of the inputs covers their hire cost: $P \frac{\partial Y}{\partial L} = w_L$ for labour, and $P \frac{\partial Y}{\partial K} = w_K$ for capital), one can get a direct measure of the parameters α and β :

$$\alpha = \frac{w_L L}{PY} \text{ and } \beta = \frac{w_K K}{PY}, \tag{9}$$

which constitute the compensation share of labour and capital in the nominal output, respectively.

[6] For the sake of simplicity we are assuming only two inputs, capital and labour.

Although competition in product markets is not perfect, a profit-maximizing firm will still set marginal revenue MR equal to marginal cost MC when it determines the factor input level, but price will be above marginal revenue (the amount of the difference being greater the more price-inelastic the demand curve). In this case, use of PY in the denominator of (9) that estimates the marginal product of labour α and the marginal product of capital β is inappropriate. Since $P > MR$, both α and β will be underestimated. In this case, the traditional multifactor productivity estimate has weights α and β that underestimate the portion of growth that comes from increases in the factors labour and capital. In turn, estimates of multifactor productivity will be biased upwards.

There are really two parts to the increase in output that would be expected from an increase in factor inputs. One part is due to the increase in factor use weighted by existing marginal products and the other to an increase in the value of marginal products arising from the exploitation of economies of scale as a plant increases in size. The latter is missed in estimates of multifactor productivity that assume constant returns to scale.

Appropriate corrections can be made to the denominators PY in (9) based on estimates of the ratio $\frac{P}{MR} = \left(1 + \varepsilon_{PY}\right)$ (where ε_{PY} is the inverse demand elasticity). This in turn can be calculated from estimates of the demand elasticity facing firms in an industry because a profit-maximizing firm is expected to set the price-cost markup ($\frac{(P-MC)}{MC}$) equal to the inverse of the demand elasticity it faces, and to set $MR = MC$. Using these two conditions, the ratio $\frac{P}{MR}$ can be calculated and P can be adjusted downward to equal MR, and a new set of weights can be devised to calculate multifactor productivity, which will be smaller than before.

It is also useful to examine the problems that arise from estimating multifactor productivity by using the dual to the production function. The dual total cost function C that corresponds to the Cobb-Douglas production function is[7]

$$C = e^{\gamma t} Q^{\frac{1}{(\alpha+\beta)}} w_L^{\frac{\alpha}{(\alpha+\beta)}} w_K^{\frac{\beta}{(\alpha+\beta)}}, \tag{10}$$

where γ is an unknown parameter. The dual multifactor productivity growth estimate derived from (10) $\left(\gamma \equiv \varepsilon_{Ct}\right)$ is simply

$$\varepsilon_{Ct} = \frac{\Delta C}{C} - \frac{1}{(\alpha+\beta)}\frac{\Delta Y}{Y} - \frac{\alpha}{(\alpha+\beta)}\frac{\Delta w_L}{w_L} - \frac{\beta}{(\alpha+\beta)}\frac{\Delta w_K}{w_K}. \tag{11}$$

Under the assumption of constant returns to scale, full capacity and perfect competition, $\varepsilon_{Ct} = -\varepsilon_{Yt}$. But if there are economies of scale $\alpha + \beta > 1$, then the estimates of the dual multifactor productivity growth would generally be smaller than are derived under the assumption of constant returns to scale.

[7] See Nerlove (1965) for an early treatment of the importance and equivalence of the dual cost function.

It is also useful to examine the effects of having prices not equal to marginal revenue on the estimation of the coefficients $\frac{\alpha}{(\alpha+\beta)}$ and $\frac{\beta}{(\alpha+\beta)}$ in this equation.

The first order conditions used to estimate the coefficients on the prices of labour and capital in the dual cost function are straightforward: the first derivative of the cost function, with respect to the price of a factor, is set equal to the quantity of the factor used (Shephard's lemma); that is $\frac{\Delta C}{\Delta w_L} = L$ for labour, for example, or it is expressed in terms of elasticity, $\frac{\Delta C}{\Delta w_L}\frac{w_L}{C} = \frac{w_L L}{C}$. Using (10), yields

$$\frac{\alpha}{(\alpha+\beta)} = \frac{w_L L}{C}, \tag{12}$$

and similarly for capital,

$$\frac{\beta}{(\alpha+\beta)} = \frac{w_K K}{C}. \tag{13}$$

It should be noted that a correct estimation of the parameters $\frac{\alpha}{(\alpha+\beta)}$ and $\frac{\beta}{(\alpha+\beta)}$ does not require the assumption that prices are equal to marginal revenue. It depends only on accurately estimating the share of labour and capital compensation in total costs. As long as costs are measured accurately,[8] the dual estimation technique removes the problem faced by the primal estimation technique of having to worry about whether marginal revenue can be replaced by prices. Of course, it is still necessary to accurately measure costs and to make sure that the costs of capital do not include any profits above those required to compensate capital for its opportunity cost.

8.2.2 The modified productivity measurement framework

Recognition of scale economies requires that a portion of output growth be attributed to the scale economies that cause output to grow more than proportionately to the increase in inputs. Relaxing the capacity utilization construct requires that we perform a similar exercise to take into account the portion of the output gains that are due to short-run scale economies that occur as a firm moves down a short-run cost curve towards full capacity.

Two corrections can be made to the standard dual of the cost-side methodological framework to allow for scale economies and short-run fixities in the capital stock.

1) Scale economies

First, to correct for $\varepsilon_{CY} \neq 1$ owing to scale economies, the residual that is normally estimated, ε_{Ct} , can be adjusted to yield the appropriate measure $\varepsilon_{Ct}^{\text{scale}}$, (Morisson 1992):

[8] We return to the same problem we faced in the primal case if we replace costs with revenues in the estimation process of the dual; that is, we set costs equal to revenues for the estimation of input compensation shares.

$$\begin{aligned}
\varepsilon_{Ct}^{\text{scale}} &= \frac{\dot{C}}{C} - \varepsilon_{CY}\frac{\dot{Y}}{Y} - \sum_{i=1}^{I}\omega_i \cdot \frac{\dot{w}_i}{w_i} \\
&= -\varepsilon_{CY}\frac{\dot{Y}}{Y} + \sum_i \omega_i \left(\frac{\dot{X}_i}{X_i} \right) \\
&= \varepsilon_{Ct} + \left(1 - \varepsilon_{CY}\right)\frac{\dot{Y}}{Y}.
\end{aligned} \tag{14}$$

The last term $\left(1 - \varepsilon_{CY}\right)\frac{\dot{Y}}{Y}$ is the amount that should be subtracted from the traditional measures $\left(\varepsilon_{Ct}\right)$ when constant returns to scale are assumed inappropriately. The adaptation in (14) reflects the fact that $\varepsilon_{CY} = \frac{MC}{AC}$. Thus, the adjustment by ε_{CY} restates the change in output in terms of its correct marginal value. Costs should not be expected to increase proportionately to output, as in equation 2, when there are economies of scale. The impact of this adjustment on traditional estimates of multifactor productivity depends on the extent of scale economies and output growth.

2) Imperfect capacity utilization

If instead $\varepsilon_{CY} \neq 1$ because $\varepsilon_{CK} \neq 0$ as a result of short-run capital fixity and, therefore, sub-optimal capacity utilization, the valuation of the quasi-fixed input at the market rental price w_K is erroneous. The valuation should instead be made in terms of the shadow value z, reflecting the true marginal product of capital. This implies an adjustment for the numerator of the share weight on the quasi-fixed input change as well as for the denominator on weights of all inputs and outputs to reflect the fact that costs should be measured as C^* not C.

This adjustment is required because the derivation of the expression measuring productivity using the dual cost approach depends on the use of Shephard's lemma to make the substitution of X_i, the cost-minimizing demand for input i, for $\frac{\partial C}{\partial w_i}$. If capital is a quasi-fixed factor, this is not valid because the firm will not be able to instantaneously choose a cost-minimizing quantity for K. When this occurs, valuation of the changes in K should be made at the shadow value z instead of w_K, and input shares should be measured in terms of C^*.

Non-optimal use of the fixed inputs implies $\varepsilon_{CY} = 1 - \varepsilon_{CK} = \frac{C^*}{C} \neq 1$. The expression for ε_{Ct} can be adjusted to yield the appropriate measure $\varepsilon_{Ct}^{\text{fixity}}$ (Morisson 1992):

$$\begin{aligned}
\varepsilon_{Ct}^{\text{fixity}} &= \left(1 - \varepsilon_{CK}\right) \cdot \frac{\dot{Y}}{Y} - \frac{z \cdot K}{C} \cdot \frac{\dot{K}}{K} - \sum_i \frac{w_i \cdot X_i}{C} \cdot \frac{\dot{X}_i}{X_i} \\
&= \varepsilon_{Ct} + \varepsilon_{CK}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K} \right).
\end{aligned} \tag{15}$$

As before, the last term in this expression can be thought of as a correction that is required if instantaneous adjustment is assumed when subequilibrium really exists. The correction depends in part on the relative growth rates of output and the quasi-fixed input K. Equation (15) has an intuitive interpretation: under the conditions of constant returns to scale, full capacity utilization and perfect competition, the dual ε_{Ct} and primal ε_{Yt} measures of multifactor productivity coincide. Therefore ε_{Ct} can be measured as the weighted sum of the labour productivity and capital productivity, that is, $\varepsilon_{Ct} = -\left[\frac{w_L L}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{L}}{L}\right) + \frac{w_K K}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right)\right]$. Because capital is fixed in the short run, w_K does not properly measure the value of the marginal product of capital. A correction that accounts for the discrepancy between the rental price of capital and its shadow price should therefore be introduced in the above formula. The adjustment factor is $\varepsilon_{CK}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right) = \frac{\left(w_K + \frac{\partial G}{\partial K}\right)K}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right) = \frac{\left(w_K K - zK\right)}{C}\left(\frac{\dot{Y}}{Y} - \frac{\dot{K}}{K}\right)$.

3) An integrated framework

Generating a fully adjusted measure of technical change from the cost side, incorporating both fixity and returns to scale, requires combining (14) and (15) as in Morrison (1992). This measure, denoted $\varepsilon_{Ct}^{\text{full}}$, accommodates the full adjustment in the standard ε_{Ct} measure:

$$\begin{aligned}\varepsilon_{Ct}^{\text{full}} &= -\varepsilon_{CY}\frac{\dot{Y}}{Y} + \sum_i \omega_i \left(\frac{\dot{X}_i}{X_i}\right) + \frac{z \cdot K}{C} \cdot \frac{\dot{K}}{K} \\ &= \varepsilon_{Ct} - \varepsilon_{CK} \cdot \frac{\dot{K}}{K} - (\varepsilon_{CY} - 1)\frac{\dot{Y}}{Y}.\end{aligned} \tag{16}$$

The long-run scale elasticity correction factor recognizes that part of the cost change (reduction) is the result of economies of scale. The fixity correction recognizes that part of the change is due to the fact that the increase in capital used is not the same as the increase in total capacity of capital.

Once these adaptations of standard productivity growth measures are made, the traditional dual measure of productivity growth can be decomposed into scale and fixity effects and a residual that Morrison (1992) has referred to as the 'true' productivity growth.

8.3 Empirical implementation

In order to implement the framework developed in the previous section, estimates are required of scale economies, capacity utilization and markups. This is done here in three steps. First, short-run elasticities are estimated from a restricted cost function, which in turn is used to estimate the capacity utilization in the economy. Second, long-run scale elasticities are estimated from short-run elasticities and capacity utilization. Third, the inverse demand function is estimated to yield price elasticities that in turn are used to estimate the price-marginal cost mark-up.

8.3.1 Econometric specification

The basic building block of our model is a translog restricted cost function and a similarly constructed output demand function. The non-constant returns to scale translog cost function has the following forms:

$$\begin{aligned}\ell n\left(\frac{G_h}{w_{sh}}\right) = {} & \beta_{oh} + \sum_i \beta_{ih}\ell n v_{ih} + \beta_{Yh}\ell n Y_h + \beta_{Kh}\ell n K_h + \beta_{th} t + \\ & \beta_{YYh}\left(\ell n Y_h\right)^2 + \beta_{KKh}\left(\ell n K_h\right)^2 + \beta_{tth} t^2 \\ & + \sum_{i \neq j}\sum_j \beta_{ijh}\ell n v_{ih}\ell n v_{jh} + \sum_i \beta_{iYh}\ell n v_{ih}\ell n Y_h \\ & + \sum_i \beta_{iKh}\ell n v_{ih}\ell n K_h + \sum_i \beta_{ith}\ell n v_{ih} t \\ & + \beta_{YK}\ell n Y_h \ell n K_h + \beta_{Yth}\ell n Y_h t + \beta_{Kth}\ell n K_h t\end{aligned} \tag{17}$$

$$i, j = L(\text{labour}), E(\text{energy}), M(\text{material}) \text{ and } S(\text{services});\ h = 1, 2, ..., h.$$

The subscripts i and j denote the variable inputs L, E, M and S, while h is an industry index. In this framework, labour input, measured in terms of hours worked, is assumed to be optimally adjusted within a year. A similar assumption is made for the intermediate inputs E, M and S. In contrast, because of gestation lags and other types of inertia, adjustment of the capital stock is assumed to be slower.

The variable cost G_h is defined as $G_h = \sum_i w_{ih} X_{ih}$ where w_{ih} and X_{ih} refer to the prices and quantities of the variable inputs L, E, M and S; and v_{ih} is the relative input price, defined as $v_{ih} = \frac{w_{ih}}{w_{sh}}$, where w_{sh} is the price of service inputs.

The corresponding inverse demand function for output is $P(Y, \Gamma)$ where Y represents the output and Γ is a vector of shift variables. These variables include the interest rate r, the implicit price index of goods and services P_{gs}, and the unemployment rate u. The inverse demand function is written as

$$\begin{aligned}\ell n P_h = {} & \theta_{oh} + \theta_{Yh}\ell n Y_h + \theta_r \ell n r + \theta_{gs}\ell n P_{gs} + \theta_u \ell n u + \theta_t t \\ & + \theta_r (\ell n r)^2 + \theta_{gs}\left(\ell n P_{gs}\right)^2 + \theta_u (\ell n u)^2 + \theta_{tt} t^2.\end{aligned} \tag{18}$$

The inter-industry differences are captured in our estimation through the following parameterization of the cost function: $\beta_{oh} = \beta_o + \sum_h \alpha_{oh} D_h$, $\beta_{ih} = \beta_i + \sum_h \alpha_{ih} D_h$, where the parameters α_{jh} are normalized with respect to the k industry $\left(\alpha_{jk} = 0\right)$; D_h refers to the industry dummies taking values 1 and 0, and h, as noted earlier, is the industry identification index (similarly, we have $\theta_{oh} = \theta_o + \sum_h \alpha_{oh} D_h$ for the inverse demand function).

Table 8.1 Manufacturing industries	
Food and Beverages	Refineries
Tobacco	Rubber
Textile	Leather
Clothing	Non-metallic Mineral
Wood and Lumber	Primary Metal
Furniture and Fixtures	Fabricated Metal
Paper	Machinery
Printing and Publishing	Electrical and Electronic
Chemical	Transportation Equipment

In our estimation, we have allowed for specific industry effects, that is,

$\beta_{Yh} = \beta_Y + \sum_h \alpha_{Yh} D_h$, $\beta_{Kh} = \beta_K + \sum_h \alpha_{Kh} D_h$,
$\beta_{th} = \beta_t + \sum_h \alpha_{th} D_h$, $\beta_{ijh} = \beta_{ij} + \sum_h \alpha_{ijh} D_h$,
$\beta_{iYh} = \beta_{iY} + \sum_h \alpha_{iYh} D_h$, $\beta_{iKh} = \beta_{iK} + \sum_h \alpha_{iKh} D_h$ and
$\beta_{ith} = \beta_{it} + \sum_h \alpha_{ith} D_h$ (similarly, we have $\theta_{Yh} = \theta_Y + \sum_h \alpha_{Yh} D_h$ for the price equation).

The system of equations (17), along with its associated share equations, should satisfy the usual regularity conditions.[9] We also assume that the error terms attached to the above equations are optimizing errors and are jointly normally distributed with zero expected value, and with a positive definite symmetric covariance matrix.

The system of equations used to estimate the parameters required by our measurement framework includes the cost function (17), the demand functions for L, E and M, and the output demand equation (18).[10]

8.3.2 Data and estimation

Estimation of the system (17) was carried out using Canadian manufacturing data for the period 1961 to 1995. In addition to estimates for the 18 manufacturing industries listed in Table 8.1, we also derived an estimate for the entire manufacturing sector by aggregating data across industries using Fisher indices.[11]

[9] In particular, for the cost function to be concave in input prices, its Hessian matrix $\left[\frac{\partial G}{\partial w_i \partial w_j}\right]_{ij}$ of second-order derivatives with respect to variable input prices should be negative semi-definite. In addition, the cost function should be non-decreasing in output and linearly homogeneous in input prices.

[10] Applying Shephard's lemma, the following share equations are obtained: $\omega_{ih} = \beta_{ih} + \sum_i \beta_{ih} \ell n v_{ih} + \sum_i \beta_{iYh} \ell n Y_h + \sum_i \beta_{iKh} \ell n K_h + \beta_{ith} t$, where $\omega_{ih} = \frac{w_{ih} \cdot x_{ih}}{G_h}$. The share of the service inputs is calculated as $\omega_{sh} = 1 - \sum_i \omega_{ih}$, since there are only $n-1$ independent equations in the model.

[11] See the methodology in Appendix 1 for the method of Fisher aggregation used.

Table 8.2 Descriptive statistics of industries 1961 to 1995	$\dot{G}$	ω_L	ω_E	ω_M	ω_S	$\dot{Y}$	$\dot{L}$	$\dot{E}$	$\dot{M}$	$\dot{S}$	$\dot{K}$
						mean values					
Food and Beverages	7.0	18.0	1.3	67.2	13.6	7.4	-0.1	1.0	2.8	2.2	1.9
Tobacco	4.9	19.2	0.5	64.1	16.2	6.1	-2.8	1.6	-0.4	1.1	-0.1
Textile	6.0	29.0	2.1	57.0	11.9	8.2	-0.1	2.6	3.1	2.3	1.5
Clothing	5.5	36.3	0.5	51.1	12.0	12.8	-0.9	2.3	2.2	0.5	1.6
Wood and Lumber	9.2	32.5	2.3	51.6	13.6	3.5	0.8	4.1	4.3	4.0	2.6
Furniture and Fixtures	8.0	39.0	1.1	44.2	15.8	5.1	1.4	2.9	3.4	3.8	2.4
Paper	8.5	27.9	7.1	50.8	14.2	7.9	0.2	2.8	3.2	4.3	3.5
Printing and Publishing	8.5	46.3	0.8	32.6	20.4	5.8	1.5	3.6	3.2	3.9	3.1
Chemical	8.9	23.5	5.9	48.0	22.6	9.5	0.9	4.6	4.2	3.5	3.4
Refineries	8.6	6.0	2.0	77.9	14.1	8.3	-0.3	6.3	2.0	2.4	0.4
Rubber	10.3	32.0	1.9	51.6	14.6	8.7	3.8	7.0	6.7	5.9	3.9
Leather	3.4	36.9	0.9	48.4	13.9	8.7	-3.1	-1.7	-1.6	-0.7	0.2
Non-metallic Mineral	7.2	34.1	6.7	40.5	18.7	7.9	0.0	0.7	2.5	2.2	-0.1
Primary Metal	7.9	23.0	7.3	57.9	11.9	8.0	0.0	2.3	3.0	2.6	2.2
Fabricated Metal	7.9	34.5	1.2	51.8	12.5	10.0	1.3	2.6	2.9	3.1	1.0
Machinery	9.1	34.7	1.0	51.2	13.1	11.9	1.9	3.2	5.6	4.4	2.9
Electrical and Electronic	9.3	34.2	0.8	51.7	13.3	9.3	0.8	2.9	7.5	4.4	3.3
Transportation Equipment	11.8	21.9	0.7	65.7	11.6	7.2	2.6	4.5	7.0	6.6	5.2

Notes:

$G = \sum_i w_i X_i$ = variable cost function, with $i = L(\text{labour}), E(\text{energy}), M(\text{materials})$ and $S(\text{services})$

s_i = cost share of variable input i

$\dot{G}$ = growth rate of the variable cost $\dot{Y}$ = growth rate of real gross output $\dot{L}$ = growth rate of hours

$\dot{E}$ = growth rate of energy input $\dot{M}$ = growth rate of materials input $\dot{S}$ = growth rate of services input

$\dot{K}$ = growth rate of capital stock net of truncated geometric depreciation

The data used are series on prices and quantities of output, capital, labour, energy, materials and services from Statistics Canada's productivity program.[12] Table 8.2 provides the mean values of the cost, input shares and the growth rates of gross output and the inputs for each industry. There are considerable variations among the industries in the cost, output and input growth rates. There are some differences among the input shares as well. Labour shares range from 6% for petroleum refineries to 46% for printing and publishing. Materials' shares range from 33% for printing and publishing to 78% for refineries. These inter-industry variations encourage the use of a specification that captures industry idiosyncrasies.

The estimation model consists of the restricted cost equation from which we construct the elasticity measures described in Section 8.3, the share equations for labour, energy and materials and the output demand equation. The share equation of services is obtained residually because of the constraint that variable cost shares must sum to one. We have pooled time-series cross section data for 18 two-digit Canadian manufacturing industries for the period 1961 to 1995 to estimate the model. Estimating the model as a pooled system not only adds structure to the model (additional degrees of freedom) but also imposes cross-equation restrictions to allow a fully integrated input-demand and output-supply model, facilitating more efficient estimates. Seemingly

[12] See Appendix 1 for the sources and concepts underlying the productivity program.

unrelated regressions (SUR) techniques were used for estimation, since the equations share common parameters.[13]

The results of the hypothesis tests using log-likelihood ratios decisively reject the joint hypothesis that the dummy industry coefficients are zero, indicating that strong inter-industry differences are present in the cost structure of the industries under consideration. The results also indicate that the model is well estimated.The square of the correlation coefficients between the actual and predicted values is high, and the standard errors of each equation are small. In addition, all the required regularity conditions are satisfied at each point in the sample. The estimates revealed that the coefficients of the model are statistically significant and have the correct sign.[14]

We also test the hypothesis that firms operate under a constant returns-to-scale technology, i.e., $\varepsilon_{CY} = 1$. The test is computed by subtracting from the consistent parameter estimates obtained from estimating the system of equations (17)—call them $\hat{\varepsilon}_{CY}$—the consistent parameter estimates obtained under the alternative hypothesis, i.e., the parameter estimates, $\tilde{\varepsilon}_{CY}$, obtained from equations system (17) with $\varepsilon_{CY} = 1$. Then the vector of parameter differences is standardized by the difference of the covariance matrices of the two sets of estimates, i.e., $M = \left(\hat{\varepsilon}_{CY} - \tilde{\varepsilon}_{CY}\right)' \left\{Cov\left(\hat{\varepsilon}_{CY}\right) - Cov\left(\tilde{\varepsilon}_{CY}\right)\right\}^{-1} \left(\hat{\varepsilon}_{CY} - \tilde{\varepsilon}_{CY}\right)$. The quadratic form computed in this way is asymptotically chi-squared with degrees of freedom equal to the number of parameters of the imposed condition. The results of our tests indicate that $M = 196 > \chi^2_{95;.005} = 134$, and thus we reject the hypothesis that firms operate under constant returns to scale. Similarly, the hypotheses that firms do not operate under constraints of fixity, $\varepsilon_{CK} = 0$, that there is no technical change, $\varepsilon_{Ct} = 0$, and output markets are competitive, $\varepsilon_{PY} = 0$, were separately tested. Each of these hypotheses was rejected $M = 210 > \chi^2_{95;.001} = 134; M = 157 > \chi^2_{95;.001} = 134;$ $M = 166 > \chi^2_{95;.001} = 114, \text{respectively}$.

8.4 Analysis of results

8.4.1 The standard non-parametric productivity growth measure

Traditional non-parametric multifactor productivity growth indices ε_{Yt} based on the K, L, E, M, S division of inputs are presented in terms of average annual growth rates in Table 8.3, and in their full form (from 1961 to 1995) in Appendix Table 8.1A. These measures are computed using standard primal-side measurement techniques, ignoring the potential existence of markups, input fixity and returns to scale.

[13] The model was also estimated for each industry, using three-stage least squares to incorporate the endogeneity of output quantity and price, and to allow for the possibility of non-static expectations on input prices as outlined by Pindyck and Rotemberg (1983). The instruments employed included lagged values of exogenous variables facing the firm, defence spending and the world oil price. Although the parameter estimates for $\varepsilon_{Ct}, \varepsilon_{CY}$ and ε_{CK} do not seem to be sensitive to the estimation technique, the estimates obtained under the three-stage least squares technique are less precise than those based on the SUR technique.

[14] Interestingly, the parameter estimates were not significantly affected by using the capital stock net of the truncated geometric depreciation as opposed to the estimate using a delayed depreciation scheme. See Chapter 3 for a discussion of the two different estimation techniques.

Table 8.3 Non-parametric productivity growth measures of Canadian manufacturing industries, 1961-1995							
	Average annual growth rate (%)				Standard deviation		
	1961-1995	1961-1973	1973-1995	Pre-1973 to post-1973 gap	1961-1995	1961-1973	1973-1995
Food and Beverages	0.35	0.68	0.17	0.51	0.86	0.67	0.90
Tobacco	0.68	0.94	0.54	0.40	3.37	2.16	3.83
Textile	1.47	1.82	1.28	0.54	2.49	2.78	2.30
Clothing	0.88	1.09	0.76	0.33	1.73	1.27	1.94
Wood and Lumber	0.81	1.06	0.67	0.39	2.43	1.43	2.79
Furniture and Fixtures	0.55	1.83	–0.13	1.96	3.30	2.14	3.62
Paper and Allied Products	0.10	0.37	–0.05	0.42	2.89	1.95	3.31
Printing and Publishing	–0.03	0.66	–0.40	1.07	2.32	1.44	2.69
Chemical and Allied Products	1.22	1.85	0.88	0.96	2.52	1.92	2.79
Refineries	0.48	0.88	0.26	0.62	1.72	2.35	1.32
Rubber and Plastic Products	1.16	2.05	0.68	1.36	2.98	2.58	3.10
Leather	0.65	0.63	0.66	–0.03	1.91	1.32	2.14
Non-metallic Mineral	0.87	2.23	0.13	2.11	3.49	3.44	3.31
Primary Metal	0.55	0.70	0.47	0.22	2.33	1.43	2.66
Fabricated Metal	0.89	1.41	0.60	0.81	1.99	2.08	1.93
Machinery	1.36	1.05	1.52	–0.47	3.27	2.81	3.48
Electrical and Electronic	1.41	2.38	0.88	1.50	2.80	3.19	2.58
Transportation Equipment	1.22	2.26	0.66	1.60	2.44	2.66	2.16
Total Manufacturing	**0.82**	**1.31**	**0.53**	**0.79**	**2.18**	**1.86**	**2.24**

The average annual growth rates reveal a post-1973 productivity growth slowdown owing to the joint effect of the oil shocks and the two major recessions of the early 1980s and 1990s. The industries that show negative growth rates in the post-1973 period are printing and publishing, paper and allied products and furniture and fixtures. With a cost share of energy of 7% over the 1961 to 1995 period, the last is the most energy-intensive industry of the Canadian manufacturing sector and should have been most affected by energy price shocks. It appears that certain other industries were also affected by the energy shock in the mid-1970s, including fabricated metal products, chemical and allied products, and rubber and plastic products, most of which are energy intensive. These industries, however, are also those that experience intense international competition. Interestingly, the only industry to exhibit a substantial increase in productivity growth over this period was machinery.

The traditional productivity growth indices are procyclical, with, for example, declines appearing in most industries around the late 1960s, mid-1970s, early and late 1980s, and early 1990s. A measure of the extent of the magnitude of these fluctuations is the standard deviation, which indicates the variability of these productivity growth rates around the mean for each industry. These measures are rather large for both durable and non-durable goods industries, with a significant increase experienced over the post-1973 period.

The observed fluctuations are systematically related to the business cycle. When this productivity growth measure is correlated with Statistics Canada's published capacity utilization measure, the correlations are positive and statistically significant.

The size of these fluctuations suggests that the underlying series have not been purged of cyclicality, that unused capacity utilization has not been fully considered in the standard estimates. It is possible to argue that technical progress occurs more or less continuously and that fluctuations of the magnitude demonstrated by existing measures are

Table 8.4 Non-parametric and parametric productivity growth measures of Canadian manufacturing industries without adjustment for scale economies, fixity and price-cost margins, ε_{Ct}, 1961-1995				
	Primal non-parametric	Dual parametric	Parametric lower bound[1]	Parametric upper bound[1]
		average annual %		
Food and Beverages	0.35	0.31	0.26	0.36
Tobacco	0.68	0.61	0.46	0.76
Textile	1.47	1.36	1.15	1.57
Clothing	0.88	0.85	0.67	1.03
Wood and Lumber	0.81	0.79	0.59	0.99
Furniture and Fixtures	0.55	0.51	0.40	0.62
Paper and Allied Products	0.10	0.13	0.10	0.16
Printing and Publishing	-0.03	0.01	0.01	0.01
Chemical and Allied Products	1.22	1.13	0.96	1.30
Refineries	0.48	0.51	0.40	0.62
Rubber	1.16	1.09	0.83	1.35
Leather	0.65	0.63	0.52	0.74
Non-metallic Mineral	0.87	0.84	0.74	0.94
Primary Metal	0.55	0.52	0.39	0.65
Fabricated Metal	0.89	0.86	0.74	0.98
Machinery	1.36	1.33	1.15	1.51
Electrical and Electronic	1.41	1.36	1.10	1.62
Transportation Equipment	1.22	1.17	0.97	1.37
Total Manufacturing	**0.82**	**0.78**	**0.64**	**0.92**

Note: 1. 95% confidence intervals.

not credible. Of course, there are opposing arguments that suggest that cyclical variations of some sort should always be found in the data, since technology is absorbed more slowly in recessions because investment is so dependent on the internal flow of funds to firms and these are procyclical.

In the end, the issue is not whether there should be any fluctuations in productivity growth, but whether the size of the fluctuations that are characteristic of standard measures is reasonable. In the succeeding sections, we ask whether an alternate methodology that directly takes into account capacity utilization produces cycles in productivity growth estimates that are less dramatic than existing estimates.

8.4.2 The parametric productivity growth measure

1) The standard measure

In order to examine the effects of economies of scale and fixity, we make use of the dual cost function and estimate multifactor productivity using multivariate analysis and the assumption of no scale economies and no capital fixity. The estimates produced are listed in Table 8.4 and compared with the standard non-parametric estimates produced by the primal approach.

Overall, the two estimates are quite similar, though not identical. The non-parametric estimate derived from the primal approach has a mean value over the period 1961-1995 of 0.82, while the parametric estimate, using the dual approach, has a value of 0.78, an estimate that is 95% of the former. At the two-digit industry level, the differences range from 2 to 11 percentage points, with most of the parametric estimates being above 92% of the value yielded by the non-parametric approach.

Table 8.5 Average annual cost elasticities, Canadian manufacturing industries, 1961-1995

	$\varepsilon_{CY}\left[= CU \cdot \varepsilon_{CY}^{L}\right]$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 1961 to 1995 period[1]	
				Lower bound	Upper bound
Food and Beverages	.813	.753	.774	0.687	0.861
Tobacco	.763	.683	.713	0.602	0.824
Textile	.781	.710	.736	0.656	0.816
Clothing	.710	.710	.712	0.624	0.800
Wood and Lumber	.700	.685	.691	0.562	0.820
Furniture and Fixtures	.756	.700	.723	0.599	0.847
Paper and Allied Products	.733	.651	.682	0.611	0.753
Printing and Publishing	.794	.739	.758	0.675	0.841
Chemical and Allied Products	.717	.608	.641	0.584	0.698
Refineries	.792	.810	.804	0.708	0.900
Rubber	.863	.798	.824	0.689	0.959
Leather	.782	.760	.771	0.675	0.867
Non-metallic Mineral	.782	.705	.735	0.659	0.811
Primary Metal	.825	.765	.788	0.682	0.894
Fabricated Metal	.909	.886	.895	0.755	1.035
Machinery	.852	.737	.779	0.714	0.844
Electrical and Electronic	.893	.739	.793	0.673	0.913
Transport Equipment	.871	.753	.796	0.725	0.867
Total Manufacturing	**.819**	**.738**	**.767**	**0.678**	**0.859**

Note: 1. 95% confidence intervals.

The parametric estimation technique lends itself more readily than the non-parametric approach to the construction of confidence intervals around the point estimate. Using the standard errors of the parameter estimates, a 95% confidence interval for the parametric estimate extends from .64 to .92—a value of about .30 percentage points.

The size of the corrections that can be made to the parametric estimates as a result of scale economies and capital fixity will now be considered in turn.

2) On scale economies and capacity utilization

a) Analysis of the results

The short-run cost elasticity (ε_{CY}) is related to both the size of long-run returns to scale (scale economies ε_{CY}^{L}) and the impact of short-run fixities (as manifested by the degree of capacity not utilized $CU \equiv \frac{C^*}{C}$). As outlined previously, $\varepsilon_{CY} = CU \cdot \varepsilon_{CY}^{L}$.

Using our model, the short-run cost elasticity and capacity utilization were estimated separately and the long-run elasticity was derived therefrom. The measure of short-run cost elasticity and the capacity utilization are presented as annual averages in Tables 8.5 and 8.6, respectively.

The measured short-run cost elasticity ε_{CY} is presented in terms of annual averages in Table 8.5, and in full index form in Appendix Table 8.2A. These measures suggest short-run scale economies exist and are quite substantial in a number of industries. On average, for the 1961 to 1995 period, the short-run scale economies are about 1.30 (the inverse of the short-run cost elasticity with a 95% confidence interval ranging from 1.16 to 1.47).

Table 8.6 Capacity utilization, Canadian manufacturing industries, 1961-1995					
	$CU = \left(\frac{C^*}{C}\right)$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 961-1995 period[1]	
				Lower bound	Upper bound
			annual average		
Food and Beverages	.995	.941	.968	0.834	1.102
Tobacco	.981	.935	.958	0.791	1.125
Textile	1.069	.901	.985	0.851	1.119
Clothing	.973	.894	.934	0.805	1.063
Wood and Lumber	.901	.996	.949	0.748	1.150
Furniture and Fixtures	.891	.845	.868	0.704	1.032
Paper	.954	.912	.933	0.818	1.048
Printing and Publishing	.945	.871	.908	0.792	1.024
Chemical	1.049	.912	.981	0.881	1.081
Refineries	.998	.945	.972	0.838	1.106
Rubber	.912	.868	.891	0.726	1.056
Leather	.962	.871	.917	0.781	1.053
Non-metallic Mineral	.951	.842	.897	0.817	0.977
Primary Metals	.971	.873	.922	0.782	1.062
Fabricated Metal	.975	.908	.942	0.769	1.115
Machinery	.957	.912	.935	0.837	1.033
Electrical and Electronic Products	.971	.981	.976	0.809	1.143
Transportation Equipment	.986	.924	.986	0.882	1.090
Total Manufacturing	**.969**	**.907**	**.940**	**0.826**	**1.088**

Note: 1. 95% confidence intervals.

Short-run scale economies increase over time,[15] especially in industries that tend to be more capital intensive and have experienced productivity growth stagnation, such as chemicals, primary metals, and pulp and paper.

The average value of capacity utilization for the entire period from 1961 to 1995, reported in Table 8.6, is 94%, with a 95% confidence interval from 83% to 109%.[16] The point estimates of capacity utilization are below 100% virtually everywhere throughout the time period. The levels are less than 90% in the furniture, rubber products and non-metallic mineral products industries, indicating that the cost consequences of short-run excess capacity are often greater than 10%.

Capacity utilization has been declining in every industry but wood and lumber and electrical and electronic products. The excess capacity has been driven primarily, especially since 1973, by a low shadow value of capital relative to its market price; in most industries a decline in the $\frac{w_K}{p}$ ratio has occurred since 1973. The estimated capacity utilization has decreased between the pre- and post-1973 period. A trend regression finds significant declines over time.

Capacity utilization is procyclical by definition. Similarly, if scale economies exist, output expansion from upward swings in the cycle cause long-run average cost declines, so this component of ε_{CY} may also be procyclical. The procyclicality of the

[15] A trend regression model finds a significant upward movement in the scale elasticity over the time period.

[16] Earlier, we rejected the hypothesis that utilization was 100% when we pooled observations for all regressions. When we look at each industry individually, we cannot reject the null hypothesis that capacity utilization, on average, is 100%.

Table 8.7 Long-run cost elasticity, Canadian manufacturing industries, 1961-1995

	$\left(\varepsilon_{CY}^{L} = \frac{MC \cdot Y}{C^{*}}\right)$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 1961-1995 period[1]	
				Lower bound	Upper bound
	annual average				
Food and Beverages	0.817	0.800	0.800	0.70	0.93
Tobacco	0.777	0.731	0.744	0.63	0.90
Textile	0.731	0.788	0.748	0.66	0.86
Clothing	0.730	0.794	0.763	0.67	0.88
Wood and Lumber	0.776	0.687	0.728	0.60	0.92
Furniture and Fixtures	0.849	0.828	0.833	0.70	1.03
Paper	0.769	0.714	0.731	0.65	0.83
Printing and Publishing	0.840	0.848	0.835	0.74	0.96
Chemical	0.683	0.666	0.654	0.59	0.73
Refineries	0.794	0.857	0.828	0.73	0.96
Rubber	0.946	0.919	0.925	0.78	1.13
Leather	0.813	0.873	0.842	0.73	0.99
Non-metallic Mineral	0.822	0.837	0.819	0.75	0.90
Primary Metal	0.850	0.877	0.854	0.74	1.01
Fabricated Metal	0.932	0.975	0.950	0.80	1.16
Machinery	0.890	0.807	0.833	0.75	0.93
Electrical and Electronic	0.919	0.753	0.813	0.69	0.98
Transportation Equipment	0.883	0.764	0.807	0.73	0.90
Total Manufacturing	**0.837**	**0.792**	**0.804**	**0.71**	**0.93**

Note: 1. Confidence intervals derived by dividing short-run cost elasticity by the 95% confidence intervals for capacity utilization.

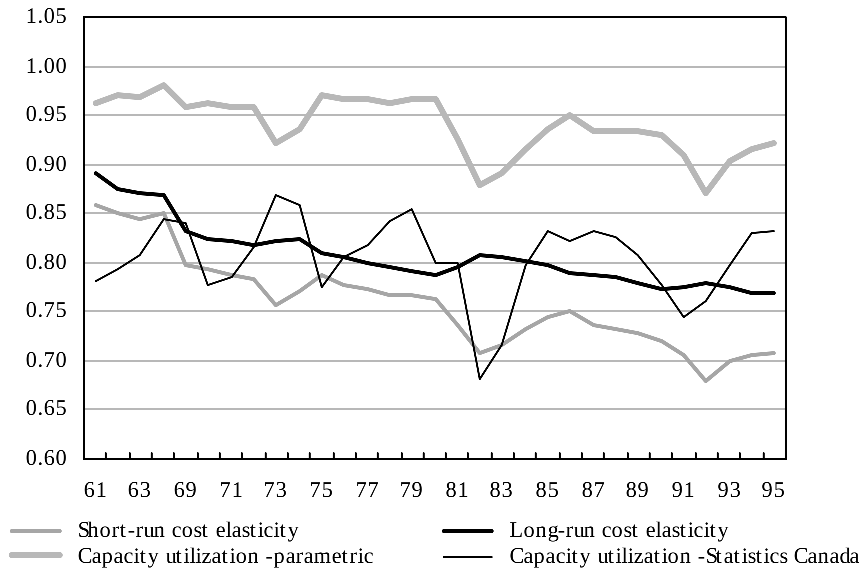
ε_{CY} measure is evident from Appendix Table 8.2A, where, for example, declines are evident for most industries in the downturns of 1970-1973, 1981-1982 and 1990-1992. To a large extent cyclical movements in ε_{CY} are driven by fluctuations in capacity utilization.

The estimates of the long-run returns to scale that are derived from the short-run elasticity and the rate of capacity utilization are provided in Table 8.7. The long-run average cost elasticity of the manufacturing sector as a whole between 1961 and 1995 is 0.80, suggesting that returns to scale are around 20%. These estimates, however, are subject to rather large confidence intervals. If we use the point estimates of the short-run cost elasticity and the upper and lower bounds for our estimate of capacity utilization, the long-run scale estimate ranges from 9% to 41%. Nevertheless, this range includes other estimates of the scale elasticity in the Canadian manufacturing sector. Baldwin and Gorecki (1986) use micro-data of manufacturing plants to estimate scale elasticities and report a figure of about 16%, an estimate not far removed from the point estimate derived here from time series data.

Both the estimate of capacity utilization CU and the estimate of long-run cost elasticity ε_{CY}^{L} decline from the first period (1961 to 1973) to the second period (1973 to 1995) and drive the declining short-run cost elasticity ε_{CY}. In particular, long-run returns to scale (the inverse of ε_{CY}^{L}) are substantial and increasing, especially in durable goods industries such as machinery, electrical and electronic products, and transportation equipment and in non-durable goods industries such as wood and lumber.

Figure 8.1 displays the long-run and short-run cost elasticities along with two different capacity utilization estimates. The first estimate of capacity utilization is generated from our parametric framework and the second, produced by Statistics Canada, is based on the ratio of actual to potential output.[17] Figure 8.1 indicates that while these alternative measures of capacity utilization display different levels, they both reveal a downward trend over the 1961 to 1995 period. With a steeper decline, the parametric measure of capacity utilization suggests that the manufacturing sector has not recovered the level of capacity of the golden era of economic growth (the pre-1973 period).

Figure 8.1 Cost elasticity and capacity utilization, manufacturing sector, 1961-1995



It is also noteworthy that long-run scale economies (the inverse of the long-run cost elasticity) increase rather smoothly (Figure 8.1). This confirms, at the sectoral level, what has already been observed at the industry level: to a large extent cyclical movements in ε_{CY} are driven by utilization fluctuations.

b) Implications of scale economies on price-marginal cost markups and the adjustment factor

The evidence that there are scale economies in the Canadian manufacturing sector is critical since it implies the existence of a price-marginal cost markup, which has implications for the accuracy of the standard productivity measures. The existence of both scale economies and price-marginal costs markups may lead to bias in the measure of the output share that is used in the measurement of the standard productivity growth (see equation (1)). It is, therefore, useful to estimate the size of markups implicitly being earned in the manufacturing sector.

Markups

The markups that we estimate are presented in Table 8.8 in terms of annual averages, and in Appendix Table 8.3A in their full form. The results, consistent with those found by Morrison (1994), indicate that, for the 1961 to 1995 period, the markups are about 29% with a confidence interval ranging from 16% to 39%.

[17] Statistics Canada's estimates of capacity utilization are built from surveyed estimates of capacity utilization rates. Capacity utilization is defined as the ratio of existing output to maximum or capacity output. See Statistics Canada (1994) p. 53.

Table 8.8 Average annual markups, Canadian manufacturing industries, 1961-1995					
	$\frac{P}{MC}\left[=\frac{1}{(1+\varepsilon_{PY})}\right]$				
	1961-1973	1973-1995	1961-1995	Confidence intervals for the 1961-1995 period[1]	
				Lower bound	Upper bound
			%		
Food and Beverages	1.258	1.213	1.280	1.151	1.365
Tobacco	1.361	1.313	1.390	1.192	1.530
Textile	1.248	1.224	1.264	1.156	1.340
Clothing	1.281	1.292	1.276	1.164	1.398
Wood and Lumber	1.441	1.449	1.440	1.216	1.666
Furniture and Fixtures	1.200	1.179	1.212	1.024	1.376
Paper	1.444	1.446	1.445	1.329	1.559
Printing and Publishing	1.206	1.134	1.247	1.105	1.307
Chemical	1.612	1.543	1.661	1.521	1.703
Refineries	1.205	1.223	1.200	1.062	1.348
Rubber	1.226	1.165	1.261	1.072	1.380
Leather	1.227	1.241	1.220	1.107	1.347
Non-metallic Mineral	1.165	1.168	1.166	1.067	1.263
Primary Metal	1.228	1.268	1.208	1.104	1.352
Fabricated Metal	1.161	1.175	1.156	1.003	1.319
Machinery	1.397	1.265	1.471	1.323	1.471
Electrical and Electronic	1.309	1.165	1.388	1.136	1.482
Transportation Equipment	1.118	1.151	1.211	1.059	1.177
Total Manufacturing	**1.291**	**1.254**	**1.313**	**1.163**	**1.389**

Note: 1. 95% confidence intervals

A secular increase in the price-marginal cost markup is evident,[18] although significant year-to-year variations occur. This tendency is more apparent from the year-to-year changes appearing in Appendix Table 8.3A than from the overall averages. The only industries experiencing a clear downward trend in markups are primary metals, fabricated metal products, clothing, wood and lumber, leather products and refineries. This is consistent with intensifying international competition in the apparel, lumber and primary metal markets. In the petroleum refining industry, it has probably arisen from an increase in crude oil prices relative to international refined product prices, which has provided downward pressures on domestic profit margins. Some other industries facing increasing international competition, such as pulp and paper and non-metallic mineral products, have had quite constant margins. Interestingly, markups in high-technology industries such as electrical and electronic products, machinery, transportation equipment and chemical products increased between 1961-1973 and 1973-1995.

The estimate of the price-marginal cost markup is generally compatible with the estimates of the long-run elasticity of scale. We can see this by making use of our simple primal estimate derived from the Cobb-Douglas production function used in the section on the scale economies. If the marginal revenue is adjusted downward by about 28% for both the labour and capital weight, as is required by this estimate of the markup, the sum of the two coefficients would in effect yield an estimate of the long-run scale economies of about 1.28. The estimate of the long-run scale economies derived from the non-parametric technique is 1.23%.

[18] Once more, a trend regression is significant.

Table 8.9 Full adjustment factor, Canadian manufacturing industries, 1961-1995					
	ADJ			Confidence intervals for the 1961-1995 period[1]	
	1961-1973	1973-1995	1961-1995	Lower bound	Upper bound
			average annual level		
Food and Beverages	0.974	0.986	0.964	0.794	1.174
Tobacco	0.970	1.002	0.950	0.715	1.254
Textile	0.919	0.956	0.897	0.763	1.099
Clothing	0.913	0.918	0.906	0.722	1.118
Wood and Lumber	0.996	1.013	0.986	0.681	1.366
Furniture and Fixtures	0.868	0.892	0.848	0.614	1.170
Paper	0.985	1.060	0.941	0.811	1.169
Printing and Publishing	0.914	0.900	0.922	0.740	1.098
Chemical	1.034	1.106	1.010	0.882	1.192
Refineries	0.969	0.969	0.972	0.769	1.194
Rubber	1.009	1.005	1.006	0.739	1.325
Leather	0.946	0.971	0.927	0.742	1.171
Non-metallic Mineral	0.856	0.913	0.822	0.704	1.023
Primary Metal	0.967	1.046	0.924	0.751	1.203
Fabricated Metal	1.039	1.068	1.024	0.762	1.358
Machinery	1.088	1.077	1.084	0.939	1.236
Electrical and Electronic	1.038	1.040	1.025	0.761	1.349
Transportation Equipment	0.945	1.002	0.912	0.773	1.024
Total Manufacturing	**0.974**	**0.996**	**0.950**	**0.783**	**1.184**

Note: 1. 95% confidence intervals.

Output share of the standard productivity framework

Recall that the $ADJ = \frac{\varepsilon_{CY}}{(1+\varepsilon_{PY})}$ variable shown in (3) measures the extent to which nominal output is close to economic costs and, accordingly, if economic profits are equal to zero. It provides an indication of the accuracy of the output share used in the standard productivity framework. With $ADJ \neq 1$, it follows that the standard productivity framework uses a measured output share that encompasses market returns that are not related to just improvements in efficiency. However, it may be the case that the output share constitutes a reasonable approximation of the cost share as counteracting effects may arise between the cost elasticity and markups.

The results, reported in Figure 8.2, show that for the manufacturing sector ADJ was close to unity during the pre-1973 period and it declined slightly thereafter. For the 1961 to 1995 period, ADJ averaged 0.97. But this estimate is subject to a high degree of uncertainty as evidenced by its large confidence interval (from 0.78 to 1.19). In addition, there is a wide discrepancy between revenue and costs at the individual industry level (Table 8.9). These findings reflect the fact that revenue (and therefore the revenue share) appearing in (1) embodies returns to all characteristics of the production process. In contrast, costs C (and thus the cost shares) include only ex ante returns to inputs, so (2) captures the effect of technical change independent of these other effects.

8.5 Correcting the productivity measure for scale and fixity

The productivity growth rates that allow for economies of scale and capital fixity are reported in Table 8.10. On average, the corrected value is 0.60 over the period 1961 to 1995, while the uncorrected value was 0.78 (Table 8.4) for a reduction of 0.18 percentage points.

Figure 8.2 Markups, capacity utilization and short-run cost elasticity, manufacturing sector, 1961-1995

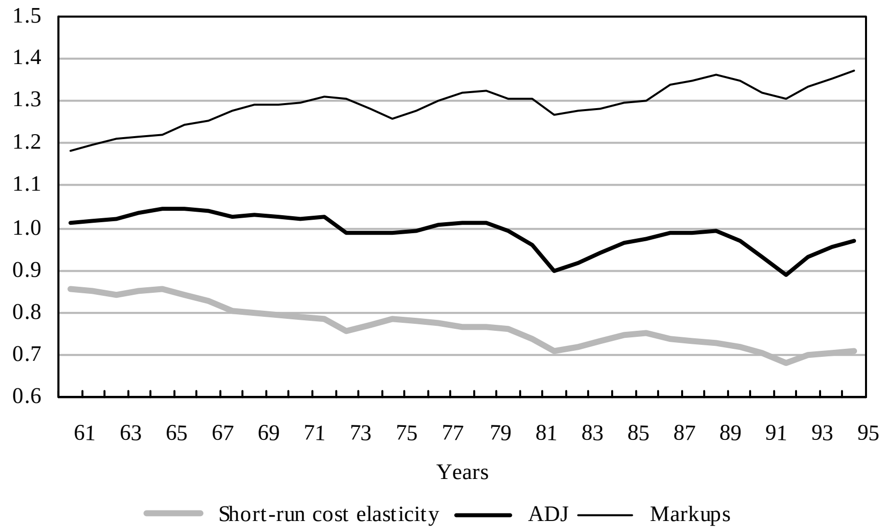
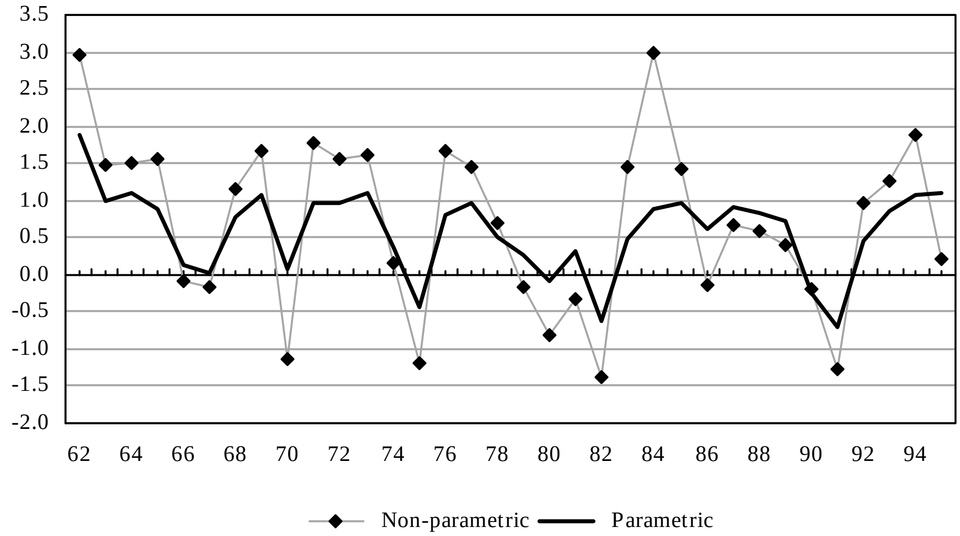


Table 8.10 Parametric productivity growth measures of Canadian manufacturing industries, 1961-1995

	Average annual growth rate				Standard deviation		
	1961-1995	1961-1973	1973-1995	Pre-1973 to post-1973 gap	1961-1995	1961-1973	1973-1995
Food and Beverages	0.27	0.44	0.09	0.355	0.4	0.4	0.3
Tobacco	0.41	0.88	0.20	0.678	2.4	1.4	2.8
Textile	0.84	1.12	0.68	0.443	1.1	1.4	0.9
Clothing	0.58	0.95	0.44	0.515	1.5	1.0	1.7
Wood and Lumber	0.52	0.84	0.33	0.510	1.4	1.1	1.5
Furniture and Fixtures	0.25	0.63	0.08	0.546	1.6	0.7	1.9
Paper	0.25	0.30	0.26	0.042	1.2	0.6	1.4
Printing and Publishing	0.18	0.76	0.02	0.742	1.5	1.3	1.7
Chemical	1.10	1.10	1.14	-0.042	1.6	0.9	1.9
Refineries	0.57	0.87	0.48	0.399	1.2	1.6	1.0
Rubber	0.68	1.24	0.50	0.743	1.7	1.4	1.8
Leather	0.68	0.64	0.69	-0.047	1.1	1.0	1.1
Non-metallic Mineral	0.86	1.69	0.45	1.240	1.7	1.9	1.5
Primary Metal	0.45	0.65	0.36	0.284	1.1	1.0	1.2
Fabricated Metal	0.59	0.67	0.58	0.096	0.9	0.7	0.9
Machinery	0.98	1.21	0.93	0.281	1.8	1.8	1.8
Electrical and Electronic	1.09	1.32	1.03	0.290	1.6	1.2	1.8
Transportation Equipment	0.98	1.14	0.91	0.231	1.1	0.8	1.2
Total Manufacturing	**0.60**	**0.82**	**0.49**	**0.33**	**1.00**	**0.89**	**1.03**

Figure 8.3 Alternate estimates of multifactor productivity, manufacturing sector



It is important to note that the precision of this point estimate is subject to substantial uncertainty. Our correction is derived from an estimate of capacity utilization of 0.94 with a confidence interval stretching from 0.82 to 1.088. In other words, our estimate cannot rule out that capacity utilization on average was not different from 1. It is also derived from a long-run elasticity of 1.24 but with confidence intervals for this estimate stretching from 1.08 to 1.41. If we choose an estimate of capacity utilization of 1 and an estimate of the long-run returns to scale of no more than 8%, our correction factor would be less than 0.02% or no more than 5% of the original estimate.

It is also useful to consider differences in the time path of the corrected parametric estimates and the uncorrected estimates. For this purpose, we compare the differences in the parametric dual to the non-parametric primal estimates. A comparison of the indices in Tables 8.3 and 8.10 shows larger differences between the corrected parametric and uncorrected non-parametric estimates of productivity growth during the pre-1973 period. For example, for total manufacturing, unadjusted growth rates for the periods 1961-1973 and 1973-1995 are 1.3% and 0.5%, respectively. The corresponding adjusted values are 0.82% and 0.49%, respectively. Scale economies accounted for 37% of total productivity growth in the first period, but only 7% in the second period. After allowance has been made for scale economies, there is less of a productivity growth slowdown than is shown by the traditional estimates—though it has not disappeared completely. Thus, a partial explanation of the post-1973 slowdown arises from changes in the importance of scale economies.

The revised productivity measures have somewhat smaller secular and cyclical fluctuations. The standard deviations of the revised productivity growth rates for the manufacturing sector as a whole over the periods 1961-1995, 1961-1973 and 1973-1995 were only 50%, 33%, and 44%, respectively, of the standard deviations of the original growth rates. This tendency to 'smooth' the productivity growth measure is corroborated by an examination of the year-to-year fluctuations reported in Appendix Table 8.4A, and in Figure 8.3 of ε_{Yt} (traditionally measured) and $\varepsilon_{Ct}^{\text{full}}$ for total manufacturing.

8.6 Conclusion

This chapter has examined the impact of relaxing several standard assumptions about economies of scale, instantaneous capacity adjustment and competitive pricing that are embedded in the estimation techniques used for productivity measures.

Assumptions are required in the measurement process to facilitate estimation—just as they are in developing theory to provide simple abstractions. They are meaningful in theory if they distil a complex problem into a representation that captures the essence of the process that is being examined. They are meaningful for the measurement process if they do the same.

It is recognized that not all markets are perfectly competitive. Nor are all markets characterized by constant returns to scale. Moreover, capacity utilization is not 100% at all times.

There are two issues that statisticians must address. First, does the relaxation of these assumptions make much of a difference to the estimates that are produced? Second, can we place much faith in the precision of the estimates of these complex phenomena?

This chapter provides evidence derived from an experiment that asks whether accurate estimates can be made of the component of productivity growth that is due to the exploitation of economies of scale and capacity utilization. It has done so by asking what fraction of the measures that are normally used to represent productivity growth can be attributed to these components.

Our research has provided a point estimate that up to 20% of productivity growth is due to the exploitation of economies of scale and fixity of capital. However, it should be noted that these measures are not very precise. The size of the bounds that accompany these estimates means we should tread carefully in assigning a specific contribution to economies of scale in the productivity growth.

There is another reason to proceed cautiously in this area. It is not clear that the exploitation of scale economies and disembodied technical progress can really be separated. A firm can rarely simply take advantage of scale economies by scaling up the production process. To do so often requires innovation and technical breakthroughs. For example, there are a number of production processes that take advantage of the scale economies associated with a production process involving a cylindrical shape—pipelines, chemical plants, petroleum refineries. Each of these processes involves a particular type of scale economy—that is, a cylinder's circumference, which has to be constructed out of materials, increases less quickly as it is expanded than does the volume contained therein. As such, volume or quantity produced increases faster than the input materials required. As plants grow larger, declining average costs result. However, taking advantage of these economies often requires technological breakthroughs. For example, the jumbo jet, which involved these types of economies, needed better engines. The Bessemer steel furnace required special fans to blow oxygen through molten metal, and petroleum refineries required new engineering techniques to master mass distillation processes.

This does not mean that productivity growth does not emerge from the exploitation of economies of scale. Rather it means that it is probably inappropriate to say that the decomposition we have performed here precisely isolates technical change from the exploitation of scale economies. A good part of the latter is the result of technical improvements in production processes. At best, we can say that we have divided the technical progress component into two items—one that is related to the exploitation of economies of scale and one that is separate from it.

References

Baldwin, J.R. and P.K. Gorecki. 1986. *The Role of Scale in Canada-U.S. Productivity Differences in the Manufacturing Sector: 1970–79.* Volume 6. Collected Research Studies of the Royal Commission on the Economic Union and Development Prospects for Canada. Toronto: University of Toronto Press.

Berndt, E.R. and M. Fuss. 1986. "Productivity Measurement Using Capital Asset Valuation to Adjust for Variations in Utilization." *Journal of Econometrics.* 33: 7–30.

Berndt, E.R. and D.M. Hesse. 1985. "Measuring and Assessing Capacity Utilization in the Manufacturing Sector of Nine OECD Countries." *European Economic Review.* 30: 961–989.

Bernstein, J.I. and P. Mohnen. 1991. "Price-Cost Margins, Exports and Productivity Growth: With an Application to Canadian Industries." *Canadian Journal of Economics.* 24: 638–659.

Denny, M., M. Fuss, and L. Waverman. 1981. "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries, with an Application to Canadian Telecommunications." *Productivity Measurement in Regulated Industries*. T.G. Cowing and R. Stevenson (eds). New York: Academic Press.

Domowitz, I.R., G. Hubbard and B. Petersen. 1988. "Market Structure and Cyclical Fluctuations in United States Manufacturing." *The Review of Economics and Statistics.* 70: 55–66.

Hall, R.E. 1988. "The Relation between Price and Marginal Cost in United States Industry." *Journal of Political Economy.* 96: 921–947.

Morrison, C.J. 1985. "Primal and Dual Capacity Utilization: An Application to Productivity Measurement in the U.S. Automobile Industry." *Journal of Business and Economic Statistics.*3, 4: 312–324.

———. 1992. "Unravelling the Productivity Growth Slowdown in the United States, Canada and Japan: The Effects of Subequilibrium Scale Economies and Markups." *The Review of Economics and Statistics.* 64: 381–393.

———. 1994. "The Cyclical Nature of Markups in Canadian Manufacturing: A Production Theory Approach." *Journal of Applied Econometrics.* 9: 269–282.

Nerlove, M. 1965. *Estimation and Identification of Cobb-Douglas Production Functions*. Chicago: Rand McNally.

Ohta, M. 1975. "A Note on the Duality between Production and Cost Functions: Rate of Returns to Scale and Rate of Technical Progress." *Economic Studies Quarterly.* 25: 63–65.

Pindyck, R.S. and J.J. Rotemberg. 1983. “Dynamic Factor Demands, Energy Use and the Effects of Energy Price Shocks.” *American Economic Review.* 73: 1066–1079.

Solow, R. M. 1958. “Technical Change and the Aggregate Production Function.” *The Review of Economics and Statistics.* 39: 312–320.

Statistics Canada. 1994. *Fixed Capital Flows and Stocks, 1961–1994*. Historical. Catalogue no. 13-568. Occasional. Ottawa: Minister responsible for Statistics Canada.

Appendix Table 8.1A Non parametric annual multifactor productivity growth rates of the Canadian manufacturing sector

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
					Percentage					
1962	1.47	-0.84	6.25	2.47	2.48	1.73	0.04	2.20	3.42	5.96
1963	0.57	3.28	2.89	1.71	3.65	2.99	1.33	0.31	2.53	0.69
1964	0.45	2.26	0.28	-0.15	1.42	0.58	1.76	-0.52	3.61	2.07
1965	1.36	1.78	-1.60	1.09	-0.22	4.28	-1.23	-0.08	1.47	1.48
1966	0.98	-3.04	-1.63	0.87	-0.51	1.30	-1.25	0.34	0.85	1.17
1967	0.19	-2.15	-0.45	-1.51	0.08	0.57	-3.48	0.13	-0.82	-4.07
1968	-0.51	-0.89	5.17	1.60	3.20	0.86	0.87	0.19	1.34	1.19
1969	0.38	1.55	3.78	0.22	1.83	2.96	2.62	0.67	2.77	-1.22
1970	0.17	1.83	-1.19	-0.12	0.29	-2.94	-0.78	-1.67	-2.46	0.35
1971	1.99	3.76	3.22	2.56	0.80	1.39	-0.67	0.28	3.01	1.15
1972	0.50	2.31	4.43	2.07	-0.06	5.48	2.75	2.87	2.59	-0.30
1973	0.65	1.73	1.09	2.36	-0.09	2.98	2.70	3.35	4.06	2.44
1974	-0.40	3.14	0.56	0.49	-1.60	-7.66	1.54	0.03	-0.16	-2.55
1975	-1.55	-1.54	1.22	1.83	-1.95	-1.83	-9.99	1.46	-6.24	-0.13
1976	2.51	-0.90	2.08	2.33	4.61	4.62	6.18	5.05	2.75	-0.02
1977	1.24	4.63	4.01	2.52	3.15	0.79	0.19	3.01	1.34	3.31
1978	-0.08	-2.04	3.86	3.23	-1.26	3.57	3.32	2.87	3.40	-1.68
1979	0.05	0.73	3.11	2.41	-0.99	-2.24	-0.57	-1.30	-0.40	-1.87
1980	-0.94	0.73	-0.12	-1.17	2.81	-1.41	0.36	-0.02	-3.34	0.80
1981	-0.54	-0.84	1.42	0.10	0.60	1.50	-2.29	-0.41	2.69	1.46
1982	-0.19	0.38	-3.74	-2.99	-1.84	-7.66	-3.80	-3.58	-2.38	0.26
1983	-0.19	-1.26	7.48	-0.30	8.12	4.79	4.41	0.87	3.43	0.74
1984	0.60	-1.14	0.34	3.18	4.03	1.62	1.46	2.83	3.75	0.15
1985	0.71	-2.14	1.03	1.07	2.90	1.56	0.59	0.15	2.62	0.49
1986	-0.41	-2.52	3.41	1.77	0.08	-0.01	0.36	-0.40	2.36	0.04
1987	0.48	7.56	0.66	2.67	4.72	-3.99	0.74	-1.85	1.91	1.62
1988	-0.11	3.61	-1.54	-3.80	-1.40	-2.06	-1.21	-1.08	1.70	0.47
1989	-1.15	2.27	0.51	0.66	-1.09	-0.67	-3.61	-1.19	2.60	1.29
1990	1.02	-4.18	-1.58	1.00	-1.94	1.57	-2.90	-0.68	-0.82	0.43
1991	0.46	0.69	-1.39	-1.42	-1.49	-4.44	-1.22	-7.57	-4.16	-0.29
1992	0.25	-1.89	1.54	1.08	1.59	5.94	2.20	-2.57	0.18	0.28
1993	-0.16	-4.92	2.15	-1.56	0.06	1.24	2.54	-3.19	2.66	-0.96
1994	1.17	12.43	2.69	2.56	-1.63	2.69	1.92	-0.44	3.05	1.18
1995	1.11	0.74	1.10	1.53	-1.80	0.55	-0.13	-0.10	3.32	0.97
					Average					
1961-95	0.36	0.74	1.50	0.89	0.84	0.61	0.14	0.00	1.25	0.50
1961-73	0.68	0.96	1.85	1.10	1.07	1.85	0.39	0.67	1.86	0.91
1973-95	0.20	0.66	1.30	0.85	0.68	0.06	0.12	-0.21	1.06	0.37
					Standard Deviation					
1961-95	0.86	3.37	2.49	1.73	2.43	3.30	2.89	2.32	2.52	1.72
1961-73	3.61	0.67	2.16	2.78	1.27	1.43	2.14	1.95	1.44	1.92
1973-95	6.78	0.90	3.83	2.30	1.94	2.79	3.62	3.31	2.69	2.79

Appendix Table 8.1A Non parametric annual multifactor productivity growth rates of the Canadian manufacturing sector (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
					Percentage				
1962	8.56	3.01	6.85	2.93	4.68	5.58	7.53	3.97	2.97
1963	2.17	1.29	1.45	1.98	2.00	0.43	1.35	3.70	1.49
1964	2.44	2.73	3.70	1.65	3.98	4.80	4.35	0.66	1.51
1965	1.22	-0.22	1.60	1.25	3.08	0.97	2.75	3.36	1.56
1966	1.76	-0.92	0.40	-0.40	-0.64	2.18	-0.57	-1.47	-0.08
1967	-0.11	-0.64	-4.88	-1.49	-1.06	-2.58	-3.74	4.05	-0.15
1968	3.93	0.39	3.12	2.32	0.74	-0.25	2.68	2.02	1.15
1969	1.56	0.81	1.93	1.20	0.73	2.89	2.92	4.23	1.66
1970	-2.25	0.65	-1.76	-0.25	-2.34	-1.14	-1.68	-3.97	-1.12
1971	0.85	1.25	6.63	-1.26	1.75	-3.89	2.95	5.13	1.76
1972	1.66	-1.21	6.21	-0.31	1.62	1.26	5.45	3.05	1.56
1973	3.14	0.45	2.22	0.87	2.65	2.80	5.10	2.72	1.62
1974	-3.77	2.74	-0.31	-1.62	1.85	3.71	-0.37	1.40	0.16
1975	-3.91	1.35	-1.73	-1.82	-3.44	-2.32	-3.26	0.80	-1.19
1976	4.21	3.72	1.03	-0.62	1.97	1.52	4.39	1.42	1.67
1977	4.79	0.58	-0.74	4.09	0.15	1.43	3.34	0.76	1.45
1978	2.40	4.77	1.71	3.99	0.63	1.34	-1.20	0.66	0.71
1979	1.87	-2.80	0.15	-3.35	-0.94	4.74	5.11	-0.89	-0.15
1980	-3.02	0.70	-5.62	0.05	1.81	-0.56	2.21	-5.57	-0.82
1981	1.41	1.26	-1.45	-3.70	0.70	-1.74	0.41	1.49	-0.32
1982	-1.35	-0.95	-4.54	-3.19	-2.73	-4.65	-4.46	0.13	-1.38
1983	3.97	2.65	5.50	4.00	0.17	-1.31	-0.91	2.49	1.46
1984	5.08	2.56	5.00	6.27	2.59	10.84	2.64	4.47	2.98
1985	1.95	0.15	4.56	2.46	2.16	3.85	2.01	1.26	1.42
1986	-3.09	0.55	1.93	-2.52	2.67	2.38	0.43	-0.99	-0.14
1987	1.27	0.57	3.39	2.12	0.55	0.84	0.85	-0.73	0.67
1988	-3.09	-1.85	-0.81	-1.02	-0.65	3.51	-0.16	3.57	0.59
1989	-1.62	0.95	-2.27	1.77	0.50	0.10	3.00	1.18	0.40
1990	0.23	-2.71	-4.30	-0.01	0.58	0.49	-0.85	-0.61	-0.20
1991	-2.30	-2.37	-5.52	0.31	-2.54	-4.07	-2.15	-2.17	-1.26
1992	4.65	3.66	2.05	1.91	1.93	1.15	3.02	0.81	0.98
1993	4.00	-0.32	4.31	2.13	0.19	6.73	0.32	2.72	1.27
1994	3.59	1.97	2.46	-1.21	4.96	5.42	3.86	3.53	1.89
1995	-1.20	-2.23	-0.83	1.19	0.57	1.45	1.82	-0.72	0.22
					Average				
1961-95	1.21	0.66	0.92	0.58	0.91	1.41	1.45	1.25	0.72
1961-73	2.08	0.63	2.29	0.71	1.43	1.09	2.42	2.29	1.16
1973-95	0.84	0.67	0.27	0.53	0.71	1.64	1.09	0.77	0.52
					Standard Deviation				
1961-95	2.98	1.91	3.49	2.33	1.99	3.27	2.80	2.44	2.18
1961-73	2.35	2.58	1.32	3.44	1.43	2.08	2.81	3.19	2.67
1973-95	1.32	3.10	2.14	3.31	2.66	1.93	3.48	2.58	3.59

Appendix Table 8.2A Cost elasticity of Canadian manufacturing industries

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
1961	0.83	0.82	0.83	0.76	0.70	0.82	0.81	0.88	0.83	0.81
1962	0.83	0.83	0.86	0.76	0.66	0.82	0.80	0.88	0.82	0.80
1963	0.82	0.82	0.86	0.74	0.64	0.82	0.78	0.85	0.80	0.80
1964	0.82	0.82	0.87	0.75	0.71	0.82	0.79	0.84	0.80	0.80
1965	0.82	0.81	0.84	0.76	0.73	0.81	0.78	0.82	0.80	0.79
1966	0.82	0.79	0.82	0.76	0.75	0.79	0.75	0.80	0.76	0.79
1967	0.81	0.78	0.79	0.74	0.72	0.77	0.73	0.79	0.75	0.79
1968	0.81	0.74	0.74	0.70	0.70	0.74	0.69	0.75	0.68	0.79
1969	0.81	0.71	0.71	0.68	0.69	0.73	0.67	0.73	0.64	0.79
1970	0.81	0.71	0.71	0.65	0.71	0.72	0.69	0.73	0.62	0.79
1971	0.81	0.71	0.71	0.65	0.72	0.71	0.69	0.73	0.62	0.80
1972	0.80	0.70	0.72	0.64	0.71	0.68	0.71	0.73	0.61	0.79
1973	0.79	0.69	0.72	0.64	0.66	0.61	0.64	0.70	0.58	0.77
1974	0.80	0.71	0.73	0.64	0.66	0.61	0.64	0.73	0.61	0.78
1975	0.80	0.70	0.70	0.72	0.69	0.67	0.69	0.75	0.64	0.79
1976	0.78	0.70	0.70	0.72	0.75	0.68	0.69	0.77	0.63	0.79
1977	0.77	0.70	0.72	0.72	0.77	0.74	0.69	0.78	0.64	0.80
1978	0.77	0.69	0.69	0.70	0.75	0.73	0.70	0.81	0.64	0.81
1979	0.77	0.70	0.69	0.70	0.76	0.74	0.68	0.81	0.67	0.82
1980	0.75	0.70	0.70	0.69	0.75	0.74	0.69	0.81	0.67	0.83
1981	0.73	0.69	0.70	0.69	0.67	0.67	0.67	0.81	0.66	0.81
1982	0.72	0.65	0.70	0.70	0.68	0.65	0.59	0.76	0.56	0.79
1983	0.73	0.66	0.71	0.71	0.70	0.67	0.66	0.77	0.57	0.79
1984	0.74	0.68	0.71	0.71	0.69	0.68	0.67	0.79	0.60	0.82
1985	0.74	0.67	0.68	0.71	0.69	0.69	0.65	0.69	0.60	0.82
1986	0.74	0.68	0.70	0.72	0.71	0.69	0.64	0.71	0.62	0.84
1987	0.75	0.68	0.69	0.72	0.71	0.69	0.64	0.75	0.61	0.84
1988	0.75	0.67	0.67	0.72	0.71	0.68	0.64	0.74	0.62	0.85
1989	0.75	0.69	0.71	0.73	0.71	0.69	0.63	0.71	0.62	0.85
1990	0.75	0.69	0.74	0.71	0.60	0.68	0.62	0.70	0.60	0.81
1991	0.74	0.68	0.75	0.69	0.58	0.68	0.61	0.68	0.57	0.81
1992	0.73	0.67	0.76	0.69	0.57	0.64	0.60	0.61	0.54	0.78
1993	0.75	0.67	0.73	0.75	0.62	0.69	0.61	0.66	0.56	0.80
1994	0.75	0.67	0.72	0.78	0.65	0.72	0.62	0.74	0.57	0.81
1995	0.75	0.67	0.70	0.80	0.67	0.73	0.62	0.73	0.59	0.82
Average										
1961-95	0.77	0.71	0.74	0.71	0.69	0.71	0.68	0.76	0.64	0.80
1961-73	0.81	0.76	0.78	0.71	0.70	0.76	0.73	0.79	0.72	0.79
1973-95	0.75	0.68	0.71	0.71	0.68	0.68	0.65	0.74	0.61	0.81
Standard Deviation										
1961-95	0.03	0.05	0.06	0.04	0.05	0.06	0.06	0.06	0.08	0.02
1961-73	0.01	0.06	0.07	0.05	0.03	0.07	0.06	0.06	0.09	0.01
1973-95	0.02	0.01	0.02	0.04	0.05	0.04	0.03	0.05	0.04	0.02

Appendix Table 8.2A Cost elasticity of Canadian manufacturing industries (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
1961	0.97	0.84	0.82	0.84	0.95	0.96	0.94	0.93	0.86
1962	0.96	0.83	0.83	0.84	0.95	0.93	0.92	0.91	0.85
1963	0.96	0.82	0.84	0.84	0.94	0.92	0.91	0.90	0.84
1964	0.94	0.83	0.84	0.87	0.94	0.91	0.92	0.90	0.85
1965	0.93	0.84	0.83	0.87	0.94	0.90	0.94	0.91	0.86
1966	0.90	0.84	0.80	0.86	0.92	0.86	0.94	0.87	0.84
1967	0.90	0.82	0.78	0.85	0.91	0.85	0.94	0.85	0.83
1968	0.83	0.77	0.75	0.81	0.88	0.81	0.88	0.85	0.80
1969	0.80	0.74	0.75	0.80	0.88	0.78	0.85	0.89	0.80
1970	0.77	0.74	0.75	0.80	0.89	0.79	0.84	0.87	0.79
1971	0.77	0.73	0.76	0.79	0.88	0.81	0.84	0.83	0.79
1972	0.75	0.73	0.73	0.79	0.88	0.80	0.85	0.83	0.78
1973	0.75	0.65	0.67	0.76	0.87	0.76	0.83	0.80	0.76
1974	0.80	0.65	0.70	0.77	0.87	0.76	0.85	0.83	0.77
1975	0.84	0.71	0.71	0.79	0.88	0.78	0.85	0.86	0.79
1976	0.83	0.79	0.72	0.79	0.87	0.76	0.82	0.83	0.78
1977	0.80	0.79	0.73	0.78	0.88	0.75	0.81	0.81	0.77
1978	0.78	0.82	0.73	0.78	0.88	0.75	0.80	0.79	0.77
1979	0.78	0.85	0.75	0.78	0.88	0.75	0.79	0.77	0.77
1980	0.77	0.84	0.76	0.79	0.89	0.72	0.77	0.78	0.76
1981	0.73	0.76	0.65	0.78	0.90	0.64	0.74	0.75	0.74
1982	0.72	0.73	0.63	0.75	0.88	0.61	0.72	0.74	0.71
1983	0.73	0.78	0.67	0.75	0.87	0.71	0.73	0.73	0.72
1984	0.71	0.78	0.68	0.74	0.87	0.71	0.71	0.77	0.73
1985	0.73	0.78	0.71	0.73	0.87	0.71	0.72	0.83	0.75
1986	0.77	0.77	0.76	0.73	0.89	0.77	0.72	0.81	0.75
1987	0.79	0.74	0.75	0.75	0.89	0.78	0.71	0.75	0.74
1988	0.82	0.75	0.77	0.73	0.91	0.79	0.70	0.74	0.73
1989	0.82	0.76	0.76	0.72	0.90	0.78	0.69	0.73	0.73
1990	0.84	0.74	0.75	0.73	0.90	0.71	0.70	0.74	0.72
1991	0.84	0.72	0.69	0.75	0.90	0.71	0.68	0.71	0.71
1992	0.89	0.74	0.66	0.75	0.88	0.71	0.67	0.65	0.68
1993	0.87	0.75	0.67	0.75	0.89	0.73	0.65	0.69	0.70
1994	0.87	0.79	0.67	0.76	0.89	0.78	0.67	0.69	0.71
1995	0.86	0.80	0.65	0.79	0.90	0.77	0.65	0.68	0.71
Average									
1961-95	0.82	0.77	0.73	0.78	0.89	0.78	0.79	0.80	0.77
1961-73	0.86	0.78	0.78	0.83	0.91	0.85	0.89	0.87	0.82
1973-95	0.80	0.76	0.71	0.76	0.89	0.74	0.74	0.76	0.74
Standard Deviation									
1961-95	0.07	0.05	0.06	0.04	0.02	0.08	0.09	0.07	0.05
1961-73	0.09	0.06	0.05	0.04	0.03	0.07	0.04	0.04	0.03
1973-95	0.05	0.05	0.04	0.02	0.01	0.05	0.06	0.06	0.03

Appendix Table 8.3A Markups of Canadian manufacturing industries

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
1961	1.18	1.15	1.17	1.28	1.39	1.13	1.40	1.06	1.13	1.13
1962	1.19	1.18	1.17	1.27	1.44	1.14	1.40	1.06	1.21	1.15
1963	1.20	1.21	1.17	1.27	1.45	1.14	1.41	1.08	1.30	1.17
1964	1.21	1.22	1.17	1.27	1.40	1.15	1.42	1.10	1.32	1.18
1965	1.20	1.23	1.19	1.28	1.42	1.17	1.44	1.12	1.35	1.19
1966	1.20	1.28	1.21	1.29	1.40	1.18	1.45	1.14	1.46	1.21
1967	1.21	1.33	1.22	1.29	1.43	1.18	1.44	1.15	1.59	1.22
1968	1.23	1.37	1.24	1.30	1.45	1.19	1.46	1.17	1.69	1.23
1969	1.23	1.41	1.25	1.31	1.45	1.20	1.47	1.18	1.77	1.25
1970	1.25	1.42	1.26	1.32	1.49	1.21	1.46	1.15	1.79	1.27
1971	1.25	1.43	1.28	1.31	1.49	1.22	1.47	1.16	1.80	1.28
1972	1.24	1.43	1.28	1.31	1.52	1.22	1.49	1.18	1.81	1.30
1973	1.18	1.42	1.29	1.30	1.50	1.20	1.50	1.20	1.83	1.31
1974	1.18	1.41	1.26	1.29	1.42	1.20	1.48	1.16	1.79	1.22
1975	1.20	1.40	1.26	1.30	1.40	1.20	1.45	1.11	1.69	1.19
1976	1.23	1.41	1.26	1.30	1.38	1.20	1.46	1.13	1.75	1.19
1977	1.24	1.42	1.27	1.30	1.40	1.21	1.46	1.17	1.81	1.19
1978	1.23	1.46	1.28	1.30	1.38	1.21	1.47	1.20	1.91	1.22
1979	1.22	1.46	1.29	1.29	1.34	1.22	1.47	1.20	1.93	1.19
1980	1.23	1.43	1.25	1.28	1.31	1.21	1.44	1.21	1.86	1.16
1981	1.25	1.43	1.24	1.26	1.29	1.20	1.43	1.21	1.86	1.15
1982	1.27	1.38	1.21	1.26	1.25	1.18	1.41	1.22	1.71	1.14
1983	1.27	1.39	1.24	1.26	1.28	1.20	1.42	1.24	1.70	1.14
1984	1.26	1.35	1.24	1.27	1.30	1.20	1.43	1.28	1.61	1.17
1985	1.27	1.36	1.24	1.27	1.33	1.21	1.43	1.30	1.62	1.18
1986	1.29	1.36	1.26	1.27	1.37	1.21	1.43	1.30	1.57	1.22
1987	1.36	1.41	1.29	1.28	1.44	1.22	1.45	1.31	1.63	1.22
1988	1.37	1.41	1.29	1.28	1.48	1.24	1.47	1.32	1.62	1.24
1989	1.35	1.41	1.28	1.28	1.53	1.24	1.47	1.31	1.65	1.23
1990	1.35	1.38	1.28	1.27	1.54	1.23	1.44	1.31	1.57	1.21
1991	1.34	1.31	1.27	1.27	1.56	1.23	1.43	1.31	1.37	1.21
1992	1.32	1.29	1.26	1.26	1.58	1.22	1.40	1.29	1.34	1.20
1993	1.35	1.32	1.26	1.26	1.69	1.22	1.42	1.29	1.39	1.20
1994	1.36	1.35	1.26	1.26	1.70	1.22	1.42	1.29	1.48	1.21
1995	1.38	1.37	1.27	1.27	1.66	1.23	1.44	1.30	1.50	1.21
Average										
1961-95	1.26	1.36	1.25	1.28	1.44	1.20	1.44	1.21	1.61	1.21
1961-73	1.21	1.31	1.22	1.29	1.45	1.18	1.45	1.13	1.54	1.22
1973-95	1.28	1.39	1.26	1.28	1.44	1.21	1.45	1.25	1.66	1.20
Standard Deviation										
1961-95	0.06	0.08	0.04	0.02	0.11	0.03	0.03	0.08	0.21	0.04
1961-73	0.02	0.11	0.05	0.02	0.04	0.03	0.03	0.05	0.26	0.06
1973-95	0.07	0.04	0.02	0.02	0.13	0.01	0.03	0.07	0.17	0.04

Appendix Table 8.3A Markups of Canadian manufacturing industries (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
1961	1.08	1.24	1.11	1.22	1.12	1.17	1.10	1.08	1.18
1962	1.10	1.23	1.12	1.22	1.13	1.18	1.12	1.11	1.20
1963	1.10	1.23	1.12	1.24	1.13	1.19	1.12	1.12	1.21
1964	1.11	1.24	1.14	1.24	1.14	1.21	1.12	1.12	1.22
1965	1.13	1.23	1.15	1.26	1.15	1.24	1.14	1.13	1.22
1966	1.15	1.24	1.16	1.28	1.17	1.27	1.16	1.16	1.24
1967	1.16	1.24	1.17	1.26	1.18	1.27	1.16	1.16	1.26
1968	1.18	1.24	1.18	1.28	1.19	1.28	1.19	1.18	1.28
1969	1.20	1.24	1.19	1.28	1.19	1.30	1.20	1.19	1.29
1970	1.22	1.25	1.19	1.31	1.20	1.30	1.19	1.14	1.29
1971	1.24	1.26	1.20	1.30	1.21	1.30	1.18	1.16	1.30
1972	1.23	1.25	1.22	1.33	1.22	1.34	1.20	1.18	1.31
1973	1.25	1.25	1.23	1.30	1.23	1.37	1.24	1.22	1.31
1974	1.22	1.23	1.21	1.28	1.21	1.34	1.21	1.17	1.28
1975	1.15	1.23	1.19	1.24	1.19	1.32	1.17	1.14	1.26
1976	1.17	1.23	1.19	1.24	1.19	1.34	1.19	1.17	1.28
1977	1.22	1.24	1.20	1.25	1.22	1.38	1.23	1.20	1.30
1978	1.24	1.25	1.21	1.27	1.21	1.43	1.25	1.22	1.32
1979	1.23	1.25	1.20	1.26	1.22	1.47	1.27	1.22	1.32
1980	1.19	1.24	1.18	1.22	1.23	1.47	1.27	1.16	1.31
1981	1.21	1.24	1.17	1.22	1.20	1.49	1.28	1.14	1.31
1982	1.19	1.24	1.15	1.16	1.14	1.41	1.26	1.11	1.27
1983	1.21	1.24	1.16	1.16	1.15	1.39	1.28	1.15	1.28
1984	1.27	1.24	1.17	1.17	1.14	1.48	1.34	1.20	1.28
1985	1.28	1.22	1.17	1.18	1.16	1.52	1.32	1.21	1.29
1986	1.30	1.22	1.17	1.19	1.16	1.53	1.33	1.22	1.30
1987	1.32	1.22	1.16	1.21	1.15	1.56	1.44	1.24	1.34
1988	1.37	1.21	1.17	1.21	1.13	1.61	1.48	1.25	1.35
1989	1.35	1.21	1.15	1.22	1.12	1.57	1.53	1.28	1.36
1990	1.33	1.19	1.15	1.21	1.08	1.53	1.54	1.28	1.35
1991	1.30	1.18	1.13	1.19	1.07	1.52	1.56	1.25	1.32
1992	1.26	1.18	1.12	1.15	1.07	1.47	1.58	1.23	1.30
1993	1.29	1.18	1.11	1.15	1.10	1.50	1.69	1.24	1.33
1994	1.32	1.19	1.11	1.14	1.11	1.56	1.70	1.26	1.36
1995	1.32	1.19	1.11	1.15	1.10	1.58	1.76	1.28	1.37
Average									
1961-95	1.23	1.23	1.16	1.23	1.16	1.40	1.31	1.19	1.29
1961-73	1.17	1.24	1.17	1.27	1.17	1.26	1.17	1.15	1.25
1973-95	1.26	1.22	1.17	1.21	1.16	1.47	1.39	1.21	1.31
Standard Deviation									
1961-95	0.08	0.02	0.03	0.05	0.05	0.13	0.18	0.05	0.05
1961-73	0.06	0.01	0.04	0.03	0.04	0.06	0.04	0.04	0.04
1973-95	0.06	0.02	0.03	0.05	0.05	0.08	0.18	0.05	0.03

Appendix Table 8.4A Parametric annual multifactor productivity growth rates of the Canadian manufacturing sector

Year	Food and Beverage	Tobacco	Textiles	Clothing	Wood and Lumber	Furnitures	Pulp and Paper	Printing	Chemical Products	Refineries
					Percentage					
1962	0.73	-0.65	3.47	2.06	1.89	0.58	0.01	2.16	1.91	4.77
1963	0.29	2.52	1.61	1.43	2.78	1.00	0.53	0.31	1.41	0.55
1964	0.23	1.74	0.16	-0.13	1.08	0.19	0.71	-0.20	2.01	1.65
1965	0.68	1.37	-0.89	0.91	-0.10	1.43	-0.04	0.01	0.82	1.18
1966	0.49	-1.40	-0.50	0.73	-0.20	0.43	-0.01	0.34	0.47	0.93
1967	0.16	-0.90	-0.10	-0.80	0.06	0.19	-0.90	0.13	-0.20	-1.70
1968	-0.25	-0.68	2.87	1.33	2.44	0.29	0.35	0.18	0.75	0.95
1969	0.19	1.19	2.10	0.18	1.39	0.99	1.05	0.66	1.55	-0.90
1970	1.25	1.41	-0.10	-0.09	0.22	-0.80	-0.10	-0.90	-0.90	0.28
1971	0.99	2.89	1.79	2.13	0.61	0.46	-0.20	0.28	1.68	0.92
1972	0.25	1.77	2.46	1.73	-0.04	1.83	1.10	2.83	1.45	-0.10
1973	0.33	1.33	0.61	1.97	-0.09	0.99	1.08	3.30	2.27	1.95
1974	-0.13	3.23	0.35	-0.80	-1.00	-1.92	1.24	0.03	-0.10	-1.40
1975	-0.95	1.60	0.76	-0.89	-1.10	-0.70	0.89	1.45	-0.99	-0.12
1976	0.19	-0.93	0.90	1.09	0.98	0.66	1.12	1.08	0.26	-0.02
1977	0.20	2.70	1.40	1.75	2.40	0.50	0.15	2.36	1.40	2.20
1978	-0.03	-2.10	1.70	-1.21	-0.90	1.63	1.40	1.70	1.63	-0.90
1979	0.02	0.75	1.94	-0.80	-0.70	-1.20	-0.40	-0.70	-0.20	-0.70
1980	-0.31	0.75	-0.08	2.71	2.63	-0.80	0.28	-0.02	-1.80	0.74
1981	-0.18	-0.20	0.88	0.58	0.56	1.50	-0.70	-0.10	2.99	1.36
1982	-0.06	0.39	-0.91	-0.13	-0.35	-1.12	-0.77	-1.40	-1.10	0.24
1983	-0.06	-1.29	1.10	1.40	1.08	0.80	0.80	0.86	0.89	0.69
1984	0.20	-1.17	0.21	1.90	1.17	1.01	1.01	0.99	0.97	0.14
1985	0.24	-2.20	0.64	2.50	1.14	1.14	0.47	0.15	1.01	0.45
1986	-0.14	-2.59	2.13	0.07	0.07	-0.01	0.28	0.01	2.62	0.04
1987	0.16	7.77	0.41	4.54	4.40	-2.20	0.59	-0.70	2.12	1.50
1988	-0.04	3.72	-0.96	-0.80	-0.89	-1.10	-0.80	-1.00	1.89	0.44
1989	-0.38	2.33	0.32	-1.00	-0.78	-0.10	-1.40	-0.80	2.89	1.19
1990	0.34	-4.30	-0.80	-1.20	-1.20	1.57	-1.70	-0.40	-0.80	0.39
1991	0.15	0.71	-0.60	-0.90	-1.00	-1.80	-0.80	-4.60	-2.70	-0.10
1992	0.08	-0.80	0.96	1.40	0.80	1.10	0.80	-1.20	0.20	0.26
1993	-0.05	-5.06	1.34	0.06	0.06	1.24	1.15	-2.20	2.96	-0.70
1994	0.39	0.99	1.17	-1.57	-1.52	1.26	1.31	-0.20	1.11	1.09
1995	0.99	0.76	1.83	-0.90	-0.10	1.50	1.90	0.14	1.12	2.20
					Average					
1961-95	0.17	0.46	0.83	0.57	0.46	0.31	0.31	0.13	0.87	0.57
1961-73	0.44	0.88	1.12	0.95	0.84	0.63	0.30	0.76	1.10	0.87
1973-95	0.04	0.28	0.67	0.42	0.25	0.17	0.34	-0.05	0.81	0.48
					Standard Deviation					
1961-95	0.42	2.41	1.13	1.43	1.36	1.11	0.86	1.46	1.38	1.21
1961-73	3.61	0.41	1.42	1.44	0.98	1.06	0.68	0.62	1.29	0.95
1973-95	6.78	0.36	2.76	0.90	1.61	1.45	1.26	0.98	1.60	1.57

Appendix Table 8.4A Parametric annual multifactor productivity growth rates of the Canadian manufacturing sector (continued)

Year	Rubber and Plastic Products	Leather Products	Non-Metallic Mineral Products	Primary Metals	Fabricated Metal Products	Commercial and Industrial Machinery	Electrical and Electronic Products	Trans-portation Equipment	Manu-facturing
					Percentage				
1962	4.51	2.51	4.48	2.35	1.95	4.46	3.54	1.73	1.87
1963	1.14	1.08	0.95	1.58	0.83	0.35	0.64	1.61	1.00
1964	1.28	2.28	2.42	1.32	1.66	3.84	2.05	0.29	1.09
1965	0.64	-0.10	1.05	1.00	1.28	0.78	1.29	1.46	0.87
1966	0.92	-0.10	0.26	-0.10	-0.11	1.74	-0.25	-0.44	0.13
1967	-0.20	-0.20	-1.20	-0.80	-0.23	-1.10	-0.16	1.76	0.01
1968	2.07	0.33	2.05	1.86	0.31	-0.05	1.26	0.88	0.78
1969	0.82	0.68	1.26	0.96	0.30	2.32	1.37	1.84	1.07
1970	-0.80	0.54	-0.80	-0.10	-0.44	-0.10	-0.22	-0.18	0.07
1971	0.45	1.04	4.34	-0.90	0.73	-1.20	1.39	2.23	0.97
1972	0.87	-0.70	4.06	-0.11	0.67	1.01	2.56	1.33	0.97
1973	3.19	0.38	1.46	0.69	1.11	2.49	2.39	1.18	1.10
1974	-2.20	2.63	-0.10	-0.40	1.23	3.29	-0.18	1.25	0.37
1975	-1.50	1.30	-0.80	-1.12	-0.13	-0.79	-0.87	0.72	-0.43
1976	1.99	1.64	0.80	-0.12	1.20	1.20	2.98	1.10	0.79
1977	2.16	0.50	-0.90	2.20	0.90	1.08	3.10	0.20	0.98
1978	1.63	2.85	0.80	1.56	0.20	1.00	-0.96	0.50	0.51
1979	1.90	-1.10	0.14	-1.20	-0.11	4.21	5.54	-0.14	0.25
1980	-1.80	0.68	-2.10	0.04	1.21	0.15	2.40	-1.40	-0.08
1981	1.43	1.21	-0.80	-1.80	0.47	-0.75	0.44	1.33	0.31
1982	-1.20	-0.50	-1.10	-1.12	-0.99	-2.20	-1.25	0.11	-0.62
1983	1.04	0.79	1.01	0.74	0.11	-2.58	-0.18	1.25	0.49
1984	1.85	1.25	0.85	1.35	1.72	0.16	0.87	1.09	0.90
1985	1.99	0.14	1.16	1.78	1.44	1.15	1.11	1.12	0.98
1986	-0.91	0.52	1.74	0.77	1.78	2.12	0.47	-0.16	0.61
1987	1.29	0.55	3.05	1.76	0.36	0.74	0.92	-0.23	0.90
1988	-2.70	-0.10	-0.10	-0.40	-0.05	3.12	-0.14	3.19	0.83
1989	-1.20	0.91	-1.01	1.47	0.33	0.09	3.25	1.05	0.74
1990	0.23	-0.90	-1.50	-0.01	0.39	0.43	-0.55	-0.17	-0.26
1991	-1.40	-1.10	-1.50	0.26	-0.80	-1.12	-1.23	-0.18	-0.70
1992	1.08	0.25	0.78	0.80	0.14	-0.15	0.78	0.72	0.46
1993	2.21	-0.10	1.20	1.20	0.28	1.10	0.35	1.16	0.86
1994	1.15	0.87	1.90	-0.10	1.45	2.21	1.20	2.21	1.08
1995	1.04	0.95	0.85	1.80	1.14	1.08	1.17	0.98	1.10
					Average				
1961-95	0.68	0.62	0.73	0.51	0.60	0.88	1.03	0.86	0.59
1961-73	1.24	0.64	1.69	0.65	0.67	1.21	1.32	1.14	0.83
1973-95	0.49	0.59	0.25	0.44	0.58	0.78	0.94	0.73	0.49
					Standard Deviation				
1961-95	1.60	1.00	1.67	1.10	0.75	1.71	1.54	0.93	0.81
1961-73	1.60	1.44	0.97	1.88	1.05	0.75	1.81	1.19	1.50
1973-95	0.96	1.70	1.01	1.30	1.12	0.76	1.68	1.69	2.12

Appendix 1 – The Statistics Canada Productivity Program: Concepts and Methods

Tarek M. Harchaoui, Mustapha Kaci and Jean-Pierre Maynard

A.1 Introduction

This appendix describes the concepts and methods underlying Statistics Canada's indices of productivity growth. Its primary objective is to provide an accessible guide to the various productivity measures produced by Statistics Canada within a coherent framework that strikes a balance between theoretically desirable characteristics of productivity measures and the reality of data availability. A second objective is to indicate how Statistics Canada's productivity measures compare with those produced by the U.S. Bureau of Labor Statistics and the Organisation for Economic Co-operation and Development (OECD) for cross-country comparison purposes. Finally, the appendix provides comments on some of the conceptual and empirical obstacles to further improvements in the measure.

The publication of productivity measures has long been an important activity of Statistics Canada. This measurement program has evolved over the years, stimulated by changes in data availability, by new developments in the economics literature, and also by the needs of data users. Following the development of the Canadian System of National Accounts (CSNA) after the Second World War, Statistics Canada introduced labour productivity measures for the aggregate business sector and its major constituent subsectors.[1] More recently, the agency has developed measures of multifactor productivity. These measures, which consider the productivity of a bundle of inputs (labour, capital, and purchased goods and services[2]), are often used as 'red flags' to measure the extent to which economic performance differs across industries, across countries and over time.

Statistics Canada's productivity program has the following characteristics often shared by those of other statistical offices. First, it focuses exclusively on comparisons based on productivity growth measures as opposed to productivity levels. At present, rates of change are preferred because they avoid methodological and data problems associated with productivity level comparisons. Second, the program produces various kinds of productivity measures of the business sector and its major constituents (subsectors and industries).

[1] The definition of business sector used for productivity measures excludes all non-commercial activities as well as the rental value of owner-occupied dwellings. Corresponding exclusions are also made to the inputs. Business gross domestic product (GDP), as defined by the productivity program, represents 71% of the economy GDP in 1992. The business sector is split into the following major subsectors: goods-producing, services and manufacturing. The goods-producing subsector consists of agriculture, fishing, forestry, mining, manufacturing, construction and public utilities. Services comprise transportation and storage, communications, wholesale and retail trade, finance, insurance and real estate, and the group of community, business and personal services.

[2] Purchased goods and services are known as intermediate inputs in the CSNA.

A.2 Theory and concepts

A.2.1 Productivity measures

Productivity growth is commonly defined as the difference between the percentage change of a measure of output and the percentage change of a measure of inputs used. It is meant to capture the growth in productive efficiency arising from technical progress. Productivity growth is the growth of output not accounted for by the growth of an input or inputs.

There are various productivity growth measures. The choice between them depends on the purpose of productivity measurement and, in many instances, on data availability. In general, productivity measures can be grouped into two broad categories:

1. The first is single-factor productivity where growth in output is compared with growth of input. The most commonly used single-factor productivity measure is labour productivity (LP) growth , measured as:

$$\Delta\, LP = \Delta\, Q - \Delta\, L\,, \tag{1}$$

   where Δ refers to discrete changes in percentage with respect to time; Q and L represent, respectively, output and labour.

   Although labour productivity growth is an important measure, it is not the only way to measure gains in productive efficiency. Economic performance as measured by labour productivity must be interpreted carefully, since these estimates reflect changes in the other inputs (e.g., capital) in addition to growth in productive efficiency. The production of output requires the combination of all inputs in a technologically feasible manner. Hence, productivity is also measured in a way that compares output with the combined use of all resources, not just labour. For example, the construction of a complex plant with substantial expenditures on capital equipment but only minimal operating expenditures for labour may generate an apparently impressive labour productivity index, but the total amortized capital, plus labour cost may be much higher than those of a less complex but slightly more labour-intensive plant that would be more efficient while yielding a smaller labour productivity index. For these reasons, caution is in order in the interpretation of either rapid gains or 'disturbing slowdowns' in labour productivity growth. This sentiment is shared, incidentally, by both labour economists and productivity analysts (Griliches 1980; Rees 1980).

2. Users are therefore encouraged to consider a second way of measuring productivity growth, one that complements labour productivity growth. This second measure is known as multifactor productivity growth (MFP), the difference in the growth in output (Q) minus the growth in a bundle of inputs (I):

$$\Delta\, MFP = \Delta\, Q - \Delta\, I\,. \tag{2}$$

   Multifactor productivity growth is often characterized as arising from an outward shift in the production function resulting from technical progress. The concept of multifactor productivity, developed by Solow (1958), depends, for the sake of simplicity, upon the assumptions of constant returns to scale, perfect adjustments to the inputs and competitive markets. It measures technical progress as a residual; that is, the growth of the output is not due to the growth of the inputs. But Solow

Table A1.1 Most commonly used concepts of productivity

Concept of inputs	Concept of output	
	Gross output	Value added
Labour	–	Labour productivity
Capital	–	–
Combined capital and labour	–	Multifactor productivity
Combined capital, labour, energy, materials and services	Multifactor productivity	–

also acknowledged that multifactor productivity so measured reflects many other influences, because it is calculated as a residual.

Other research has made contributions facilitating the implementation of the multifactor productivity framework by statistical agencies. Domar (1961) demonstrated how a system of industry and aggregate production functions could be used to produce a set of industry productivity measures that are consistent with the aggregate measures for the economy as a whole. Jorgenson and Griliches (1967) showed how detailed data could be used to construct a capital aggregate without making strong assumptions about the relative marginal products of dissimilar assets. Also, it was recognized that fixed-based formulas could introduce bias into the aggregating process. Diewert (1976) showed how production functions could be used to provide a basis for determining which index number formulas were least restrictive. He developed a number of arguments detailing the attractive properties of superlative indices.

Measures of productivity differ partly because of the comprehensiveness of inputs covered. They also differ in terms of the measure of output used. There are two major distinctions—whether output is measured by value added or by gross final output. Table A1.1 lists a variety of single-factor and multifactor productivity concepts that are generally used for different analytical purposes. In the first case, the bundle of inputs consists of labour and capital. In the second case, it consists of labour, capital, energy, materials, and services.

A.2.2 Output and inputs

A.2.2.1 Output current prices

The information needed for the measurement of production activity is drawn from the income statement of individual businesses. In the income statement, revenues come mainly from sales; costs of goods and services sold include mainly purchased goods and services and labour compensation (wages and salaries and supplementary labour income).

Rearranged and modified, the income statement for the business unit provides the production account that constitutes the starting point for deriving the input-output accounts of an industry. The production account, derived from the income statement through some suitable modifications,[3] records the production attributable to the business unit in

[3] These modifications are necessary because sales (shown in the income statement) are not equal to the value of production. Sales are not equivalent to gross output because the business unit may either make sales from inventories of finished goods produced in previous periods or place current production in inventories. Thus, gross output is obtained as the sum of sales and the value of changes in inventories.

Table A1.2 Production account of producing units A1 and A2

Uses		Resources		
Producing unit A1				
Labour compensation	380	Gross output		+1,000
Surplus or compensation of capital	+120			
		Producing unit A1	120	
		Producing unit A2	+300	
		Industry B	+ 80	
		Purchased goods and services		-500
Charges against output	500	Value added		500
Producing unit A2				
Labour compensation	150	Gross output		300
Surplus or compensation of capital	+ 50			
		Producing unit A1	50	
		Producing unit A2	+ 0	
		Industry B	+50	
		Purchased goods and services		-100
Charges against output	200	Value added		200

Table A1.3 Production account of industry A (consolidation of producing units A1 and A2)

Uses		Resources		
Labour compensation	530	Gross output		1,300
Surplus or compensation of capital	+170	Intra-industry flows of goods and services	-470	
		Gross output net of intra-industry transactions		830
		Purchased goods and services (industry B)	-130	
Charges against output	700	Value added		700

terms of both goods and services produced and the income payments and other costs arising in production.

For the sake of an illustration, consider a business sector with two industries A and B, where A comprises two producing units A1 and A2. Table A1.2 displays the production accounts of these two units. For example, to produce $1,000 of output, the unit A1 consumes a portion of its own output ($120), a portion of the output produced by industry B ($80) and the whole output of the unit A2 ($300); it also hires employees who are paid $380. Once the employees and the purchased goods and services have been paid, the unit A1 is left with a residual of $120 to compensate the owners of capital.

The production account gives rise to two concepts of output. The first is value added, which is the sum of compensation of the primary inputs—labour and capital; this is also known as gross domestic product (GDP). The second is gross output, which is the sum of value added and the value of purchased goods and services. Value added constitutes an unduplicated measure of output. In addition, the sum of value added across all producing units is invariant to the degree of vertical integration between those units. In that sense, value added is perfectly additive. Table A1.3, which consolidates the information of the production units A1 and A2, shows that value added remains the same. By contrast, gross output suffers from double counting as the value of purchased goods and services by a unit has already been counted as output of another unit and the consolidation of producing units will change the measure of gross output.

Different measures of output are adopted by productivity practioners, depending on how they treat those transactions that occur within industry A (the consolidation of units A1 and A2), i.e., intra-industry deliveries of intermediate inputs. If the producing units A1 and A2 were integrated together into a single consolidated 'establishment' covering the whole industry A, then intra-industry purchases are netted out and gross output is then defined net of intra-industry transactions.[4] The production accounts of producing units A1 and A2 indicate that the inclusion of intra-industry flows of purchased goods and services adds identically to both the input and output side of industry A's production account, as the value of gross output and the value of purchased goods and services change with the exclusion of intra-industry transactions (Table A1.3).

The process of vertical integration may be pushed one step further to cover not only intra-industry sales but also inter-industry sales. The establishments of an industry may be integrated with their upstream suppliers, which may themselves be integrated upstream with their own suppliers. The associated concept of output in this case is called inter-industry output as it takes into account the inter-industry transactions (Rymes 1972; Wolfe 1991; Durand 1996). Under full integration, the output of industries becomes a function of the direct use of the industries' own primary inputs and the indirect use of the primary inputs of all upstream suppliers.

Constant prices

Productivity measures require estimates of real output produced and real inputs used in the production process. This is done by estimating the value of output and inputs in constant prices. The notion of constant prices is not one that can be defined in terms of physical units of output and inputs. There is no meaningful way to tally up, on a common physical unit of measurement, the diverse range of goods and services found in the economy. Rather, the aggregation is performed in monetary terms as the value, at fixed prices, of the goods and services included in the output and inputs.

The technique employed for deriving constant price series of value added is known as the 'double deflation' method. This involves deflating the gross output and the intermediate inputs separately and subtracting one from the other. This derivation of industry real output circumvents the problem of deflating the compensation of primary inputs, an alternative that could be used.

A.2.2.2 Inputs

Labour input

Over time the composition of the labour force has changed significantly in Canada, as in many other developed countries: more jobs are non-standard (part-time, temporary and self-employed); the distribution of hours worked has become more polarized (the number of persons working both short and long hours has steadily increased over the last two decades). If labour is measured in terms of number of employees, no consideration is given to the fact that some employees work a standard workweek and others do not. Measuring labour input as the number of hours worked deals with this aspect of heterogeneous labour input.

[4] This concept of output net of intra-industry transactions is also known as sector output (Gollop 1979).

Labour also varies considerably in terms of quality. For example, education has been increasing. Measuring labour input may be done either via simple aggregates or by aggregating different types of labour using different weights, based on their relative wage rate. The former ignores differences in quality. The latter adjusts for quality differentials by assuming that they are reflected in relative wage rates.

Capital input

Capital input shares some of the same characteristics as labour input. Capital goods purchased or rented by a firm also constitute repositories of capital services, much like employees hired for a certain period of time who can be seen as carriers of human capital and, therefore, as repositories of labour services. There is, however, an important difference between labour and capital: except for rented capital, no market transaction is actually recorded when capital provides services to its user. Therefore, unlike labour, no explicit price and quantity of the service rendered can be observed for capital. An implicit measure of the price of capital services, derived from the ratio of capital compensation to the stock of capital, captures the internal rate of return used in the cost of capital formula. This measure, which varies only across industries, is used to construct capital services at the level of the business sector or its subsectors (such as manufacturing and services).

As with labour, measures of capital growth can be made as simple aggregates across capital types (machinery versus buildings) or by weighting the different asset classes by weights that reflect differences in the capital services yielded by a dollar of assets in each category.

Intermediate inputs

Estimates of intermediate inputs such as energy, materials and services in current and constant prices are required for the construction of gross output, value added and, ultimately, multifactor productivity series. The weighted sum of the growth rates of intermediate inputs in constant prices enters into the calculation of a) value added in constant prices (double deflation technique) and b) multifactor productivity estimates based on gross output. The weights of intermediate inputs are defined as the ratio of the value of each intermediate input to gross output in current prices.

A.3 Measurement framework

A.3.1 Productivity measures at Statistics Canada

Statistics Canada publishes several sets of productivity measures for the Canadian business sector and its major constituent subsectors (goods producing, services and the manufacturing subsectors) and industries. Each set of measures involves a comparison of the growth in output and input measures, but each relies on a different methodology. The concept of business sector excludes general government, private households, nonprofit organizations and the CSNA imputation of the rental value of owner-occupied dwellings. The business sector thereby excludes activities where it is difficult to draw inferences on productivity from the CSNA output measures. Such inferences would be questionable mainly because the CSNA output measures in these areas are based largely on incomes of inputs in constant prices, where productivity growth must therefore be zero by construction.

The traditional measure of labour productivity—output per hour—constitutes the first measure of productivity introduced by Statistics Canada in the early 1960s. Output, measured net of price change, is compared to labour input, measured as hours at work in the corresponding sector or industry.

The second set of measures covers multifactor productivity. In these measures, output is again measured net of price changes, but the input measure is an aggregate of hours worked and capital service flows. Multifactor productivity estimates have been developed in recognition of the role capital growth plays in output growth.

Both labour and multifactor productivity estimates have been published annually since 1961 and are updated on a yearly basis following the annual revisions made by the CSNA. Labour productivity estimates are *published* for 109 industries, compared with 101 for multifactor productivity as capital stock estimates are not always available at the same level of industry detail as the input-output tables.[5]

Statistics Canada's productivity estimates are based on a bottom-up approach to productivity measurement. Productivity indices are estimated with the most detailed data available by industry and by goods and services. Productivity indices are *computed* for 147 industries in the case of labour productivity and 122 industries in the case of multifactor productivity and then aggregated by steps up to the total business sector. This approach, which takes advantage of homogenous information available at a fine level of detail, proves to be superior to the aggregated approach as it significantly improves the quality of the measured aggregate productivity indices.[6]

A.3.1.1 Labour productivity and related measures

Labour productivity, calculated as the difference in the growth rate between GDP at basic price and the number of hours are available at the L-level of input-output tables (147 industries of the business sector). Appendix 2 provides a list of various levels of aggregation used by the productivity program. Since input-output tables are usually three years behind the reference year,[7] more current estimates are produced by using projections of GDP for a high level of aggregation—16 industries (the S-Level of input-output tables). These projections are based on a regression model developed by Mirotchie (1996), where the Fisher GDP is regressed on the Laspeyres GDP and a set of three time dummy variables capturing the lag between the reference year and the last year for which input-output tables are available.

Parallel to the labour productivity indices, Statistics Canada's productivity program also produces other performance indicators, such as indices of compensation per hour and unit labour cost. Indices of compensation per hour measure the hourly cost to employers of wages and salaries, as well as supplemental payments, which include employers' contributions to employment insurance taxes and payments for private health insurance and pension plans.

Unit labour costs measure the cost of labour input required to produce one unit of output. The index of unit labour costs is derived by dividing the compensation index in current dollars by the output index.

[5] Input-output tables, which constitute the major source of data used in the productivity estimates, provide information on input and output for 167 industries. See section A.3.2, "Estimation procedures and data sources."

[6] As stated by Jorgenson (1990), the assumptions that are necessary to admit the existence of an aggregate production function are rather heroic. Its existence requires that such a function be the same for all industries and that producers face identical prices. He showed that estimates of productivity made at the aggregate level under these assumptions may significantly depart from those obtained by aggregating detailed industry productivity estimates, based on less stringent assumptions.

[7] The reference year is the most current year for which annual series can be produced.

A.3.1.2 Multifactor productivity

The productivity program produces four categories of multifactor productivity indices, each of which responds to a different analytical need:

1. At the level of the business sector or its sub-sectors, multifactor productivity indices are measured as the value-added output per combined unit of labour and capital input.

2. At the industry level, comparisons of gross output (i.e., value-added *plus* intermediate inputs) with a broader set of inputs constitute a second category of multifactor productivity indices, known as the **industry** indices. They measure the growth in the gross output of an industry not accounted for by the growth in all of its inputs (capital, labour and the intermediate inputs, which are the materials and services purchased from other industries). These indices do not take into account the productivity gains that take place in the (upstream) industries that produce these intermediate inputs.

3. **Intra-industry** multifactor productivity indices, in which intra-industry sales are netted out from gross output, constitute a variant of the industry indices. In this instance, multifactor productivity growth is computed as if all establishments in a particular industry were integrated together into a single consolidated establishment covering the whole industry. That establishment sells all its output outside the industry and purchases all its intermediate inputs outside the industry. Accordingly, intra-industry purchases are excluded in the intra-industry integrated inputs.

4. None of the above multifactor productivity indices of a particular industry accounts for the productivity gains made by its upstream suppliers. By contrast, the **inter-industry** multifactor productivity indices do just that. They also include the productivity gains realized in the upstream industries supplying intermediate inputs.[8]

The inter-industry index measures the growth in the output of an industry not accounted for by the growth in all its primary inputs as well as by the growth in the primary inputs used in the production of its intermediate inputs by its direct and indirect industry suppliers. The inter-industry productivity indices take into account all the primary inputs that have been used in the business sector as a whole to produce a given bundle of goods and services. They may be seen as productivity indices attached to commodity bundles rather than to industries (Durand 1994).

These four measures clearly show that the concept of multifactor productivity can be defined for various industrial aggregation levels and also for various levels of vertical integration (measures 3 and 4) (see Figures 1 to 5). This variety of multifactor productivity indices are produced to satisfy various analytical needs expressed by data users. For example, in an effort to assess the performance of an economy as a whole in the production of some bundle of goods, it would be inappropriate to consider the declining industries with low productivity gains without also looking at the performance of the industries supplying them with goods and services. The ability of sellers of automobiles to pass on price savings due to productivity gains arises from productivity improvement not just in the auto assembly sector but also in auto parts, plastic, rubber, and a host of other upstream industries.

[8] The concept and the empirical estimates were first introduced by Cas and Rymes (1991). However, contrary to Cas and Rymes, the inter-industry multifactor productivity estimates produced by Statistics Canada include the capital stock in the primary inputs rather than in intermediate inputs.

Figure 1. Business Sector

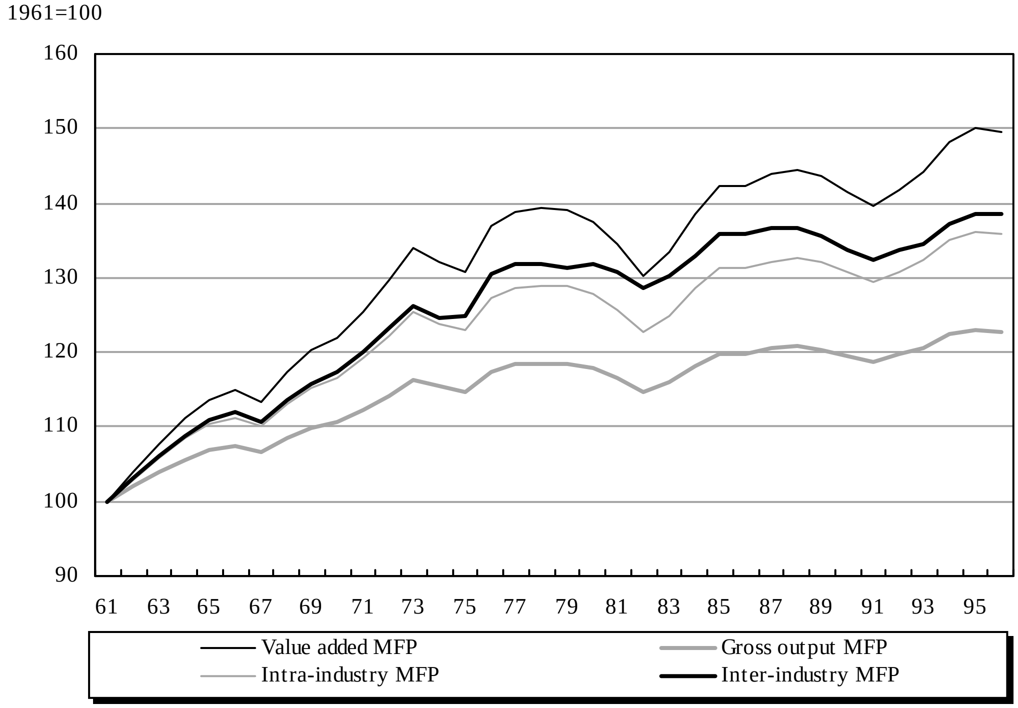


Figure 2. Business Sector excluding Agriculture

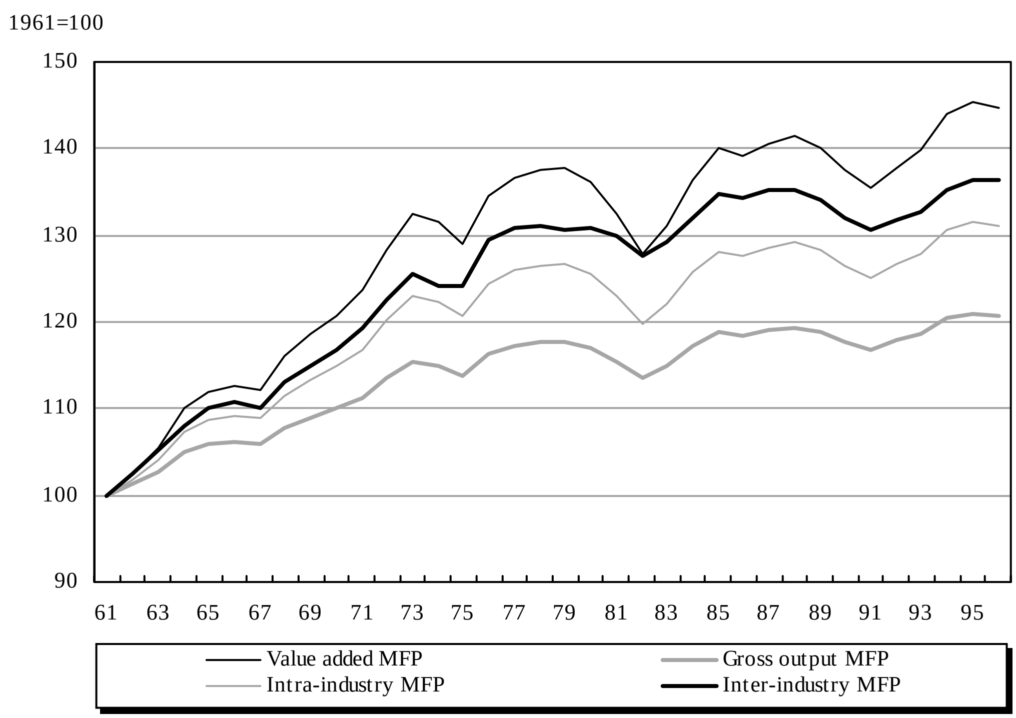


Figure 3. Business Sector – Goods Producing Industries

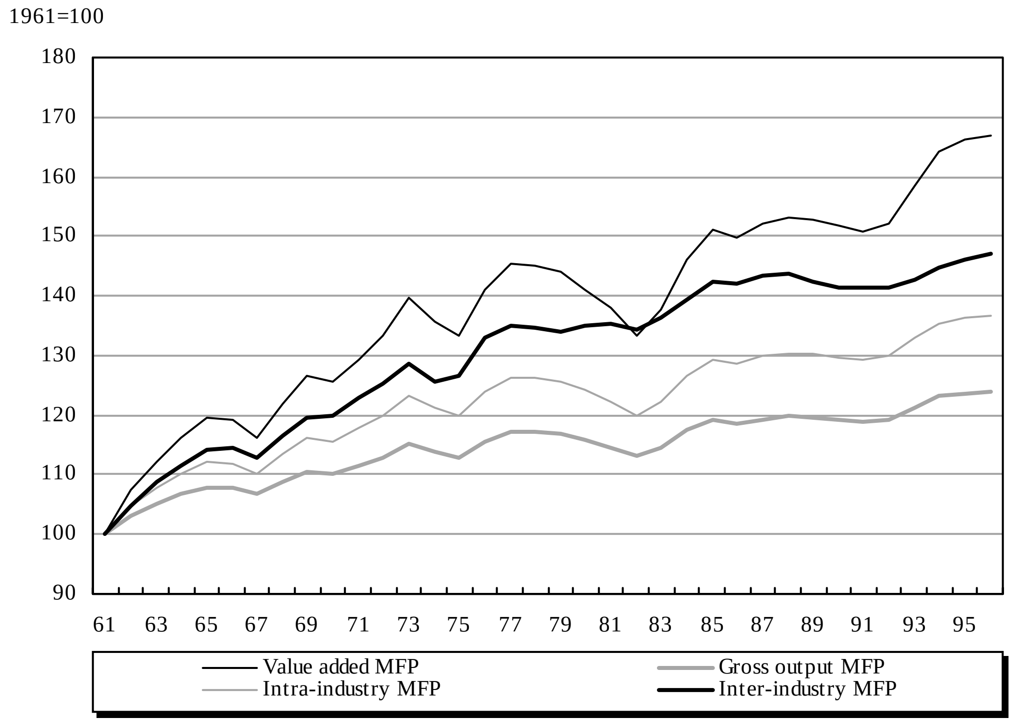


Figure 4. Business Sector – Services Producing Industries

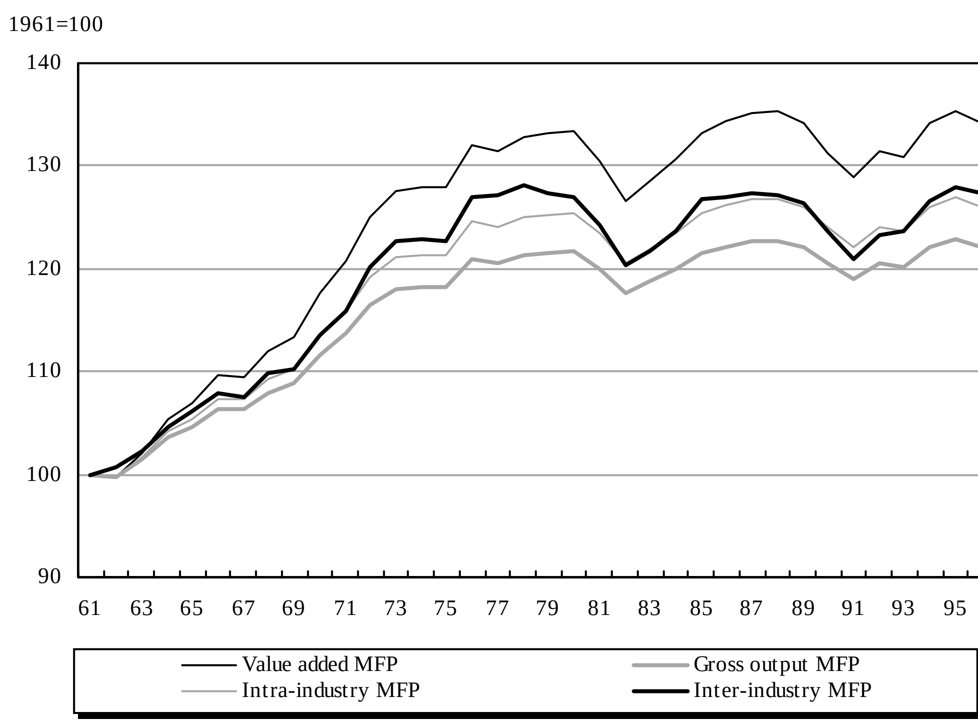
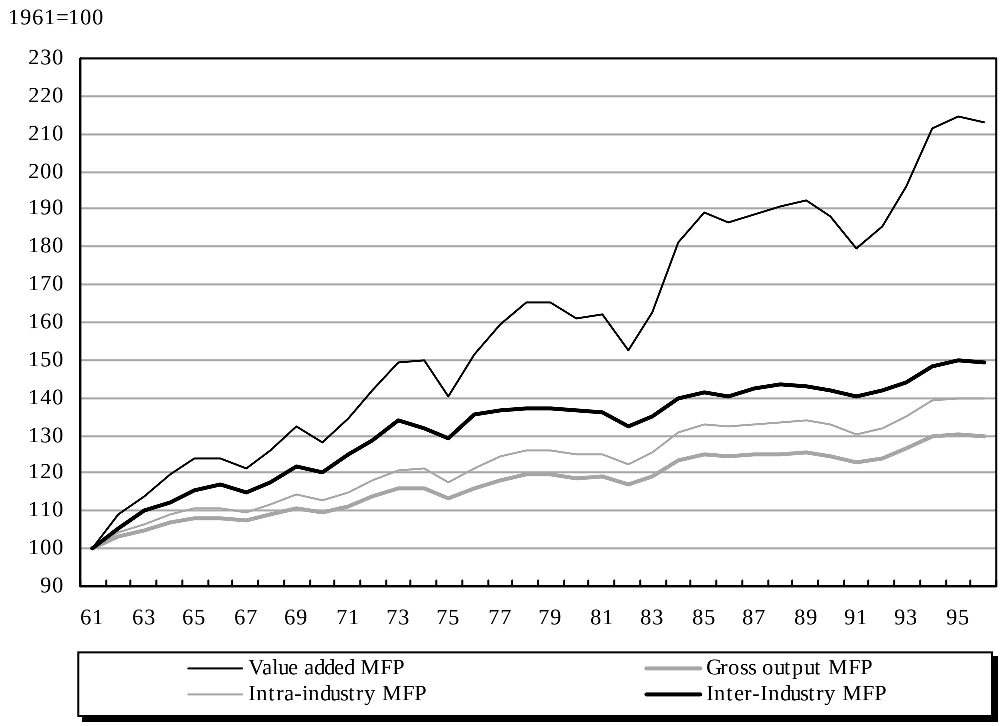


Figure 5. Manufacturing Industries



It is important to note that there are significant differences in the empirical estimates of different multifactor productivity measures (see Figures 1 to 5). The higher in the value added chain the estimate goes, the larger will be the productivity estimate. Comparisons that are made across countries that do not use the same level in the chain will contain inherent biases.

The relationship between the various multifactor productivity indices that are produced can be derived in a straightforward fashion.

The productivity growth estimates calculated using value added of an industry is just equal to the productivity growth estimates using gross output multiplied by an inflation factor, where that factor is equal to the industry's nominal gross output divided by its nominal value added. That is,

$$MFP_{VA} = \left(\frac{G}{VA}\right) \times MFP_G \tag{3}$$

where MFP_{VA} is multifactor productivity based on value added, MFP_G is multifactor productivity based on gross output, G is nominal gross output, and VA is nominal value added.

In the same way, intra-industry multifactor productivity using intra-industry value added is just

$$MFP_{II} = \left(\frac{G}{G_N}\right) \times MFP_G \tag{4}$$

where MFP_{II} is the intra-industry index, MFP_G is the gross output index, G is nominal gross output and G_N is the nominal gross output of an industry net of intra-industry sales.

Aggregating all industries together using the intra-industry measure of productivity is equivalent to considering all intermediate sales as intra-industry sales and leads to the elimination of all intermediate transactions in the business sector. This is equivalent to producing aggregate productivity measures based on value added. Because of vertical integration, the aggregate measure tends to be larger than the average of the industry measures. As a result, the higher the level of integration shown by the productivity measures, the higher the productivity gains (Durand 1996).

Like labour productivity, multifactor productivity estimates at a high level of industry detail are three years behind the reference year, but current information, based on a projection model, is available for the whole business sector and its major subsectors (Mirotchie 1996). For the multifactor productivity estimates, the model projects current information on the Fisher indices of GDP, capital stock and hours, on the basis of the Laspeyres indices of these variables and dummy trend variables.

A.3.1.3 Availability of results

New results on labour productivity (and related measures) and multifactor productivity (compensation per hour and unit labour cost) announced in Statistics Canada's official news release, *The Daily,* are published twice a year. These estimates are highly current for major sub-sectors of the business sector (one year behind the reference year) but they are three years behind the reference at the industry level. A limited amount of the most current data is provided in the news releases, but the historical series can be accessed from Statistics Canada's CANSIM database or from its Web site at www.statcan.ca. A list of CANSIM matrices can be found in Appendix 4.

Preliminary estimates of labour productivity indices and related measures (unit labour cost and compensation per hour) are generally announced in late April each year (every June for the multifactor productivity estimates). The revisions to the labour productivity estimates (and their related measures), along with the production of more current information at the industry level, are published in November (December for revised multifactor productivity estimates) of the same year, following the release of the input-output tables' results.

A.3.2 Estimation procedures and data sources

A.3.2.1 General overview

In order to produce productivity growth estimates, various data sources from Statistics Canada's survey areas and the System of National Accounts are integrated. In particular, the productivity program requires data from the following:

1. the Input Output Division, which provides the structure of the economy (in terms of industries, the commodities produced and used, and how they change over time) in both current and constant prices that is so essential to the production of aggregate estimates that are built from the ground up at the industry level;

2. the Labour Statistics Division, which provides employment numbers and hours worked to estimate the labour input;

3. the Investment and Capital Stock Division, which provides estimates of year-end net capital stock to estimate capital input; and

4. the Industry Measures and Analysis Division, which produces current estimates of GDP in constant prices, for preliminary estimates of productivity for the three most recent years.

Data that come from these different sources are conceptually adjusted and reconciled for accuracy and consistency. As such, the production of productivity measures serves as an important source of quality control on the various data series that are used in the productivity program. In almost all cases, the data received are transformed into a form that is appropriate for the calculation of productivity estimates. Using the raw data would be inappropriate, or at least would provide productivity estimates that are not as precise as required.

Efforts are made to integrate the data to ensure that measures of outputs and inputs cover the same sectors. For example, industry coverage of the productivity measures includes tenant-occupied housing but does not cover owner-occupied dwellings. Published measures of capital stock do not distinguish between these two activities. Therefore, measures of capital for tenant-occupied housing are derived for the purposes of productivity estimation.

The input-output tables are used to take into account changes in the industrial structure in the weighting procedures that calculate rates of change of outputs and inputs. Calculated rates of change in inputs or outputs are sensitive to the weights that are used to aggregate the 469 commodities that make up outputs or inputs. If these weights are not calculated correctly, estimates of rates of change will be incorrect. Using the input-output tables, the methodology in place allows these weights to change each year (using a Fisher chain weight) so as to keep the industrial structure up to date—both in the calculation of changes in inputs and changes in outputs.[9]

A.3.2.2 Output and input data: Transformation and integration

Statistics Canada's productivity measures are closely linked to the input-output tables. The input-output tables, along with data on hours and capital stock in constant prices, are used to produce the various measures of productivity growth. The production of the annual productivity estimates requires several transformations to the raw data. These transformations involve: a) the choice of the level of aggregation; b) the selection of business sector industries; c) the decision on the valuation of the outputs and inputs; and d) the assumptions on the compensation of primary inputs. Once these transformations are implemented, the resulting data on input and output are integrated with hours and capital stock data.

Transformation of data

Level of detail: Annual input-output data are imported from the input-output tables at the L-level (link) of aggregation from 1961 to the most recent year (usually three years behind the reference year) and include both business and non-business industries. This is the most detailed level for which there is a consistent definition of industries and commodities across all years. All in all, the make (output) and use (intermediate inputs)

[9] Input-output tables in constant prices make use of Laspeyres indices of quantities chained every five years.

matrices of input-output tables have 167 industries (147 non-dummy business industries and 7 dummy business industries for a total of 154 business industries and 13 non-business industries) and 469 commodities excluding indirect taxes and subsidies and compensation of the primary inputs. Indirect taxes and subsidies by commodity and by industry are compiled separately from the intermediate inputs to which they apply.

Compensation of primary inputs includes the following items applicable to incorporated businesses operating in all industries: wages and salaries and supplementary income for the compensation of labour, and other operating surplus for the compensation of capital. Mixed income includes the compensation of labour and capital employed by the unincorporated portion of the business sector.

Coverage of the business sector: Since productivity cannot be measured for non-business industries (general government, private households, non-profit organisations and owner-occupied dwellings) these industries are excluded from both the *make* and the *use* matrices in current and constant prices.[10] The same holds true for dummy industries that are fictitious industries in the input-output tables created to route real commodity consumption to other industries via dummy commodities.

In principle, dummy industries have to be excluded since they have no primary inputs and have intermediate inputs that grow at the same rate as their output, which leave them with zero productivity gains. The exclusion rules are the same as those applied to non-business industries. Therefore, only the 147 non-dummy business industries are retained in the production of productivity estimates.

The owner-occupied portion of residential housing classified in the Finance, Insurance and Real Estate subsector is excluded from the coverage of the business sector for two reasons: a) there is no adequate accounting of labour input of this industry and b) since the U.S. Bureau of Labor Statistics does not account for this industry for the same reasons, it allows Statistics Canada to construct comparable productivity estimates to those of the United States.

Valuation base for outputs, inputs and compensation: All input and output data are adjusted to correspond to prices effectively received from the sale of output and the prices paid as a result of the purchase of inputs. This means that the value of inputs should include taxes and exclude subsidies. Similarly, the value of output is taken net of output taxes and subsidies. To effect this, the value of commodity indirect taxes is distributed over the input and output commodities to which they apply. Subsidies are similarly allocated to the inputs and outputs to which they apply. This means that the concept of GDP used in the productivity estimates is not the same as the one produced by the input-output tables. GDP from the input-output tables is at factor cost, whereas GDP from the productivity program is at basic prices (i.e., GDP at factor cost *plus* indirect taxes on production *minus* subsidies on production).

The following three classes of indirect taxes are considered in the valuation of the inputs: indirect taxes on products, import duties, and indirect taxes on production. The former two apply to the intermediate inputs and the latter applies to the capital compensation. Import duties are included in the import prices of commodities and enter into the intermediate input prices valued at purchaser's prices. The indirect taxes on products

[10] The *make (use)* matrix is a matrix of the input-output tables that reflects the commodities produced (used) by the different industries.

are included in the purchaser's valuation of intermediate commodity input prices. The indirect taxes on production include property taxes as a major component and are considered part of the capital compensation.

Capital income is measured gross of direct income taxes and other non-commodity indirect taxes (mostly property taxes). Similarly, labour income is gross of income taxes.

Compensation of primary inputs: The compensation of the primary inputs in the input-output tables consists of the following variables: a) wages and salaries, b) supplementary labour income, c) mixed income, d) other operating surplus and e) net indirect taxes on production. Wages and salaries and supplementary labour income measure the compensation of paid workers. Other operating surplus is the gross capital income of incorporated businesses and includes profits before taxes, corporate income taxes, depreciation and rents on natural resources. It is computed residually in the input-output accounts as total income minus all other input costs. Net indirect taxes on production include mostly property taxes and are included in the measure of capital income.

Mixed income constitutes the earnings for both capital and labour inputs arising from the unincorporated portion of the business sector and is taken from tax records. Therefore, it includes the labour income of the self-employed and unpaid family workers, both of which are constructed by the productivity program.

The value of labour services of self-employed persons is an imputed value. The imputation is based on the assumption that the value of an hour worked by a self-employed person is the same as the value of an hour worked by an average paid worker in the same industry. This assumption is based on the premise that labour services are contracted on a temporal basis, and a measure of labour compensation should not reflect returns on investment or risk taking. However, an adjustment is made in the case of self-employed persons such as doctors, dentists, lawyers, accountants and engineers. In these cases, the average earnings of paid workers in the same industry tend to be lower than the earnings of the self-employed workers. Although self-employed workers are in the majority in these industries, the imputation of earnings for these workers at the average rate of the paid workers in these industries tends to underestimate the income of the self-employed. In this case, direct evidence on average labour income of these workers is used. Finally, for a given industry, when the imputed income for self-employment produces a higher result than total mixed income, the imputed value is made equal to mixed income.

Unpaid family workers, while not directly compensated for their services, are not a free resource, and their contribution is reflected in the net income of the firm where they are employed. However, no labour income is imputed to unpaid family workers.[11] There is no valid basis for measuring the value of their services, and it is judged that less error is generated by their exclusion from measures of labour compensation than by imputing labour income to them at the same rate as paid workers. The number of unpaid family workers is insignificant in most industries.

Labour income of self-employed and unpaid family workers is then subtracted from mixed income to arrive at the concept of other capital income, a measure of capital compensation of unincorporated businesses used by the productivity program. Other capital income is then aggregated with other operating surplus and net indirect taxes on production to obtain the total capital compensation of incorporated and unincorporated businesses.

[11] Nevertheless, data on hours and employment are available for unpaid family workers.

Integration of hours and capital stock to the transformed input-output tables

The input-output tables in constant prices do not contain data on hours worked and the end-year net capital stock in constant prices. These data undergo several conceptual transformations within the productivity program prior to their integration into the transformed input-output tables.

Labour input: The measurement of labour input requires several refinements to the concept of the head count of employees, the simplest and least differentiated measure of labour input. Such a measure neither recognizes changes in the average work time per employee nor does it reflect the role of self-employed or even differences in labour quality.

The measure of labour input starts with the concept of total jobs, consisting of wage and salary earners, self-employed and unpaid family workers, and then converts units from simple job counts to total hours worked. The rapid increase in non-standard types of employment (part-time, self-employment, etc.) stresses the importance of using hours worked as the unit of labour input in productivity measurement because they bear a closer relationship to the concept of labour services than simple job counts.

The number of hours worked may not be identical to the number of hours paid, mainly as a result of holidays and paid annual sick leave. Hours worked, rather than hours paid, is used to estimate the labour input measure because it is more closely linked to the production process.

At present, estimates of labour input used by Statistics Canada's productivity program implicitly account for differences in the composition of the labour force by industry (quality). Statistics Canada simply aggregates different types of labour at the industry level to produce an industry total. But the growth of the labour input at the level of the business sector and its constituent subsectors is the weighted sum of the number of hours worked by industry where the weights are defined in terms of the industry's share in the total labour compensation. These shares or weights will be comparatively large for industries with above-average wages and relatively small for industries with below-average wages. Assuming that above-average wages reflect above-average skills of the work force, higher weights will be applied to the growth rates of industries with a higher quality of labour. As relative wages increase in an industry, the weights will increase.

Capital input: Capital stock estimates are constructed by using the perpetual inventory method, where successive net capital stock in constant prices is related by the following equation:

$$K_t = I_t + (1 - \delta) K_{t-1}, \tag{5}$$

where K_t is the real capital stock at time t, I_t is the real investment, and δ is the (constant) rate of depreciation of the capital stock; δ need not be a constant, but almost always is assumed to be. To construct a capital stock series, one usually starts at an initial period 0 with a measure of the initial capital stock, K_0, and then calculate successive values of K_t by substituting the depreciation rate and the elements of an investment series into (5). By successive backward substitution for K_{t-1} in (5), one can relate K_t directly to the initial value for the capital stock K_0. K_t becomes a weighted sum of all past levels of investment and the depreciated value of the initial real capital stock

$$K_t = \sum_{i=0}^{t-1} (1-\delta)^i I_{t-i} + (1-\delta)^t K_0. \tag{6}$$

The amount of capital produced from a given stream of investment depends on the depreciation profile that is used. Less capital is produced when the depreciation profiles are relatively steep—where the percentage of value lost in the early years of an asset's life is large.[12] Statistics Canada produces three estimates of capital stock based on three alternative depreciation profiles: the geometric, the delayed and the linear (Statistics Canada 1999). These are derived from:

$$F(\tau, L) = \begin{cases} \delta(1-\delta)^{(\tau-1)} & (\text{geometric}) \\ \frac{L-(\tau-1)}{L-\beta(\tau-1)} - \frac{L-\tau}{L-\beta\tau} & (\text{delayed}) \\ \frac{1}{L} & (\text{linear}) \end{cases} \tag{7}$$

where F represents the value of \$1 of original investment at age τ and L is the length of life. The geometric distribution assumes that the rate of depreciation is a constant. In the geometric function, δ is set equal to $\frac{R}{L}$, where R is an arbitrary constant $(= 2)$ and $L(> 2)$ the length of life; in the delayed function, β is the curvature parameter which takes the value 0.75 for structures and 0.5 for machinery and equipment. At present, the geometric method is normalized so that the full value of an asset depreciates over its life rather than over an indefinite time span (this is the truncated geometric method).

In addition, the productivity program undertakes several changes to the estimates of capital stock net of geometric depreciation to arrive at a measurement of capital stock that is consistent with the concept of the business sector. The business sector is made up of the private non-residential and the residential components.

Private non-residential capital stock: The following 1980 Standard Industrial Classification for establishments (SIC-E) industries are deleted from the private and public estimates of capital stock published by the Investment and Capital Stock Division to arrive at the private non-residential estimates of capital stock:

- N8100 (Federal Government Service Industries)
- N8200 (Provincial and Territorial Government Service Industries)
- N8300 (Local Government Service Industries)
- O8510 (Elementary and Secondary Education)
- O8520 (Post-Secondary Non-University Education)

12 While different assumptions about depreciation have a large effect on the level of capital stock, they have much less of an effect on the rate of growth of the capital stock. See Chapter 3.

- O8530 (University Education)
- P8610 (Hospitals)

Residential capital stock: Data on total residential capital stock cover both the tenant-occupied and owner-occupied portions of the economy. Only the former is part of the business sector covered by the productivity program. The breakdown of total residential capital stock between tenant-occupied and owner-occupied portions is made on the basis of gross rent obtained from the input-output tables. The rented portion of the residential sector is then added to the non-residential capital stock to arrive at the business sector's capital stock.

In order to produce capital stock for each industry, capital can be created by simply summing across all asset categories or by deriving a weighted sum using the relative shares of each category in total compensation, where the latter are derived using rental rates of capital. At present time, Statistics Canada uses a simple aggregate across three asset classes (machinery and equipment, buildings, and engineering construction). However, in aggregating capital stock across industries, it weights each industry by its return on capital as described above. Industries with higher cost of capital will implicitly receive a higher weight using this methodology, and changes in relative cost of capital will be reflected in changing weights.

A.3.2.3 On Quality Adjustments

The measurement of multifactor productivity requires estimates of increases in factor inputs. As noted previously, Statistics Canada does so with a measure of hours-worked for labour inputs and real dollars of capital stock on the capital stock. Others (Jorgenson and Griliches, 1967; Jorgenson, 1990) have suggested that adjustments be made to the quality of each of these inputs. For example, this alternate methodology divides hours-worked into various categories (for example, males as opposed to females) and the rates of growth of each are weighted by the relative share of total wages going to each. This procedure gives higher weights to the growth rates of the group earning higher wages—and implicity assumes that higher wages are representative of higher marginal productivity and of higher quality.

This procedure redistributes some of the growth in the multifactor productivity reported here to labour and capital. If multifactor productivity is meant to help us understand the sources of growth, this procedure adds to our information in this regard. For output growth can now be attributed not just to increasing labour but to increasing labour of a certain type. As such this exercice serves to usefully supplement our existing measures and Statistics Canada is working on providing such estimates as a supplement to its normal program.

But it should be noted that these estimates are not without problems. In the first place, differences in wages may not just reflect differences in marginal products. For example, some would argue that male/female wage differentials partially reflect discrimination in labour markets. Ascribing all gender wage differentials to quality differences may be unjustified. And deciding just how much of the differentials to ascribe to real quality differences is not an easy or very precise task.

Second, this approach gradually reduces the residual that multifactor productivity is measuring towards zero—and as such the measure becomes less useful as a measure of technical progress that many users of the data use it for. Nor should we expect the quality corrected measure to be as closely related to measures of industry performance.

Finally, quality adjusted multifactor productivity series would probably have even greater measurement problems than are outlined in Chapter 3.

Despite these shortcomings, Statistics Canada is working on providing new supplementary measures in this area that will be released some time next year.

To construct the growth rate of capital stock, the productivity program makes use of the following sources of information:

1. The private non-residential and residential estimates of capital stock net of geometric depreciation in constant prices produced by the Investment and Capital Stock Division;
2. The information on compensation of capital constructed by the productivity program from the input-output tables.

A.3.2.4 On the 1997 historical revision of the System of National Accounts

Both labour and multifactor productivity measures use data that are periodically revised. About once every five years, the CSNA is rebased to keep up with the evolution of prices in the economy (Jackson 1996). In other words, the constant-price aggregates are recalculated in terms of the prices of a more recent time period. In addition, the System is revamped about once a decade to introduce new accounting conventions and improved methods of estimation. The recent changes to the System also reflect the need to bring the CSNA in line with the 1993 United Nations System of National Accounts (SNA), recommendations that will improve international comparability.[13]

The choice of a base year for the constant price estimates of output and capital stock is arbitrary, but nevertheless important. The *level* of output and capital stock and their components for any particular year can be quite different if the base year is altered. The last rebasing coincided with the release of the GDP estimates for the first quarter of 1996. At that time, the constant price series were shifted from 1986 to 1992 price weights. When the series are recalculated in this manner, the new weights are normally applied from the new base period forward. The estimates for previous years are not normally recalculated using the relative prices of the new base year in the CSNA. Rather, the already calculated constant price estimates for previous years are mechanically linked, or scaled, so as to join up with the new series. Each 'component' series is linked independently and, in some cases, the results are forced to add up through the introduction of 'adjusting entries' series (Statistics Canada 1975: 279). In this way, the growth patterns for earlier years are preserved.

Adjusting entries are calculated for GDP and its subcomponents, like gross capital formation by the CSNA. However, no adjusting entries are presently calculated to estimate capital stock and gross capital formation by the Investment and Capital Stock Division, so that their rebasing changes the growth rate of the capital stock series before the new base year. For this reason, publicly available real GDP and real capital stock estimates are not compatible. The productivity program, however, uses data from these sources that are compatible. The productivity program also uses a chained-type Fisher index in its measure of real output, labour input and capital input to address the problem that arises when rebasing is done periodically.[14] This index is a geometric mean of the chained-weighted Laspeyres and Paasche indices. Changes in this measure are calculated using the weight of adjacent years. These annual changes are 'chained' (multiplied) to form a time series that allows for the continuous incorporation of the effect of changes in relative prices and in the composition of the series over time.

[13] For a comprehensive review of the 1997 historical revision of the CSNA, see Lal (1998).
[14] Before the 1997 historical revision, the program used the Törnqvist chain index.

The 1997 historical revision also made some changes to the previous treatment of several industries in the input–output tables. The main change is the disappearance of the Government Royalties on Natural Resources Industry. In the revised version of the tables, this industry no longer exists and the commodity having the same name is now grouped with other operating surplus (capital income).

A.4 Calculation procedures

A.4.1 Labour productivity

The labour productivity (LP), or output per hour, index between two adjacent years t and $t-1$, is computed as a real value-added Fisher index[15] $\left(Y^F_{i,t/t-1}\right)$ of industry $i\left(i = 1,2,\ldots,I\right)$ divided by an index of hours worked in that industry $\left(H_{i,t/t-1}\right)$. At the business sector level, we have

$$LP_{i,t/t-1} = Y^F_{i,t/t-1} \div H_{i,t/t-1}. \tag{8}$$

The Fisher index of real value added is computed at the industry level i based on information on prices and quantities of various commodities j produced by this industry. This is accomplished in several steps:

First, the Laspeyres $\left(Y^L_{i,t/t-1}\right)$ and Paasche $\left(Y^P_{i,t/t-1}\right)$ indices of real value added $Y_{i,t/t-1}$, for t and $t-1$ consecutive periods so as to form chain indices, are computed respectively as[16]

$$Y^L_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Y_{i,j,t}}{Y_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t-1}\cdot Y_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t-1}\cdot Y_{i,j,t-1}}\right), \tag{9}$$

and[17]

$$Y^P_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Y_{i,j,t}}{Y_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t}\cdot Y_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t}\cdot Y_{i,j,t-1}}\right). \tag{10}$$

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15 Defined as the geometric mean of the Laspeyres and Paasche chain indices.

16 Recall that real value added is computed as real gross output net of real intermediate inputs.

17 Or alternatively $Y^P_{i,t/t-1} = \left[\sum_{j=1}^{469}\left(\frac{Y_{i,j,t-1}}{Y_{i,j,t}}\right)\cdot\left(\frac{p_{i,j,t}\cdot Y_{i,j,t}}{\sum_{j=1}^{469} p_{i,j,t}\cdot Y_{i,j,t}}\right)\right]^{-1}$.

Second, the Fisher chain index, $Y^F_{i,t/t-1}$, is calculated as

$$Y^F_{i,t/t-1} = \sqrt{Y^L_{i,t/t-1} \times Y^P_{i,t/t-1}}. \tag{11}$$

The Fisher index of real value-added is then constructed at a higher level of industrial aggregation (e.g., the manufacturing sector):

$$Y^F_{t/t-1} = \sum_{i=1} \omega_{it} \cdot Y^F_{i,t/t-1}. \tag{12}$$

where $\omega_{it} = \frac{V_{it} - M_{it}}{\left(\sum_{i=1} V_{it} - M_{it}\right)}$ represents the share, in terms of nominal value-added (where V_{it} and M_{it} are, respectively, gross output and intermediate inputs), of the industry i in year t.

The index of hours worked is computed as

$$H_{i,t/t-1} = \frac{\sum_{i=1}^{I} H_{i,t}}{\sum_{i=1}^{I} H_{i,t-1}}. \tag{13}$$

The computation of labour compensation per hour worked parallels the computation of output per hour.

Unit labour costs (ULC), computed as labour compensation (LC) per unit of output, highlights the relationships between unit labour costs, hourly compensations and labour productivity:

$$ULC_{i,t} \equiv \left(\frac{LC_{i,t}}{Y_{i,t}}\right) = \left(\frac{LC_{i,t}}{H_{i,t}}\right) \div \left(\frac{Y_{i,t}}{H_{i,t}}\right). \tag{14}$$

Unit labour cost is identically equal to the ratio of average hourly compensation to labour productivity; thus, unit labour costs will increase when average hourly compensation grows more rapidly than labour productivity.

A.4.2 Multifactor productivity

Like the labour productivity estimates, multifactor productivity estimates make use of a superlative aggregation scheme based on the Fisher chained index on both outputs and inputs across commodities and industries.

Estimates of the Fisher chained index require estimates of prices and quantities at a high level of detail, which is the commodity (j) for both gross output (Q_{ij}) and intermediate inputs (M_{ij}), and the industry (i) for capital (K_i) and hours (H_i).

The following steps are followed during the construction of the Fisher index for these variables.

A.4.2.1 Output and intermediate inputs

Let p_{ijt} be the price of commodity j produced by the industry i in year t and w_{ijt} the price of the intermediate input j used by the industry i during in year t, whereas Q_{ijt} and M_{ijt} represent their corresponding quantities.

- The Fisher index of output is computed at the industry level i based on information on prices and quantities of various commodities produced or used by this industry. First, the Laspeyres $\left(Q^{L}_{i,t/t-1}\right)$ and Paasche $\left(Q^{P}_{i,t/t-1}\right)$ indices of output Q_{it}, for t and $t-1$ consecutive periods are computed respectively as

$$Q^{L}_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Q_{i,j,t}}{Q_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t-1}\cdot Q_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t-1}\cdot Q_{i,j,t-1}}\right), \tag{15}$$

and

$$Q^{\mathrm{P}}_{i,t/t-1} = \sum_{j=1}^{469}\left(\frac{Q_{i,j,t}}{Q_{i,j,t-1}}\right)\cdot\left(\frac{p_{i,j,t}\cdot Q_{i,j,t-1}}{\sum_{j=1}^{469} p_{i,j,t}\cdot Q_{i,j,t-1}}\right). \tag{16}$$

Second, the Fisher index, $Q^{F}_{i,t/t-1}$, is calculated as

$$Q^{F}_{i,t/t-1} = \sqrt{Q^{L}_{i,t/t-1}\times Q^{P}_{i,t/t-1}}. \tag{17}$$

- The Fisher index of output, $Q^{F}_{t/t-1}$, is then constructed at a higher level of industrial aggregation (e.g., the manufacturing sector)

$$Q^{F}_{t/t-1} = \sum_{i=1}\omega_{it}\cdot Q^{F}_{i,t/t-1}, \tag{18}$$

where $\omega_{it} = \frac{V_{it}}{\sum_{i=1}^{146} V_{it}}$ represents the share in terms of gross output in nominal prices V_{it} of industry i in year t.[18]

[18] The same approach is developed for the multifactor productivity estimates based on the concept of value added.

A.4.2.2 Capital stock and hours

Much like the estimates of output and intermediate inputs, estimates of the Fisher chain index of capital input and labour input require series on prices and quantities. Series on quantities of labour and capital of industry i in year t are defined in terms of the number of hours h_{it} and the stock of capital in constant prices net of geometric depreciation k_{it}. The price series are constructed implicitly using the ratio of labour compensation W_{it} to the number of hours h_{it} for labour, and the ratio of capital compensation R_{it} (see "Compensation of primary inputs" in section A.3.2.2) to capital stock k_{it}, that is

$$r_{it} = \frac{R_{it}}{k_{it}}, \tag{19}$$

and

$$v_{it} = \frac{W_{it}}{h_{it}}, \tag{20}$$

where r_{it} and v_{it} represent, respectively, the (average) return on capital per unit of capital and the (average) hourly labour compensation. The construction of the Fisher chain index of capital input, $\left(K^F_{i,t/t-1}\right)$, at the industry level proceeds as follows (and similarly for labour):

- First, the Laspeyres $\left(K^L_{i,t/t-1}\right)$ and Paasche $\left(K^P_{i,t/t-1}\right)$ indices of capital input are computed as

$$K^L_{i,t/t-1} = \frac{k_{i,t} \cdot r_{i,t-1}}{k_{i,t-1} \cdot r_{i,t-1}}\,;\, K^P_{i,t/t-1} = \frac{k_{i,t} \cdot r_{i,t}}{k_{i,t-1} \cdot r_{i,t}} \tag{21}$$

The Fisher index of the capital input is then calculated as

$$K^F_{i,t/t-1} = \sqrt{K^L_{i,t/t-1} \times K^P_{i,t/t-1}}. \tag{22}$$

- The Fisher index of capital input, $\left(K^F_{t/t-1}\right)$, at a higher level of aggregation (e.g., manufacturing sector) is calculated as

$$K^F_{t/t-1} = \sum_{i=1}^{122} \omega_{it} \cdot K^F_{i,t/t-1} \tag{23}$$

where $\omega_{it} = \frac{R_{it}}{\sum_{i=1}^{122} R_{it}}$ represents the capital compensation share of the current year t of the industry i in the whole business sector.

The weight ω_{it} for each industry is based on the share of the compensation of each of the primary inputs, which makes the construction of capital input and labour input used for the multifactor productivity indices similar, albeit not identical. In that sense, a partial adjustment for the quality of the primary inputs is obtained as the change in each of these inputs used by an industry is aggregated to the economy-wide level using each industry's share in total compensation as aggregation weights. The capital (labour) weight will be large for industries displaying an above average internal return of capital (labour compensation) and small for those that do not. The weights will increase for those industries whose relative return (wage) increases over time. Some of the change in quality of capital (labour) would then be accounted for, assuming that above-average internal return of capital (labour compensation) reflect above-average 'performance' of capital (labour).

A.4.2.3 Aggregation of the inputs

- The Fisher index of the aggregate input $\left(I^F_{t/t-1}\right)$ is calculated as follows:

$$I^F_{t/t-1} = \overline{s}^K_{t/t-1} \times K^F_{t/t-1} + \overline{s}^L_{t/t-1} \times L^F_{t/t-1} \ , \qquad (24)$$

where $\overline{s}^L_{t,t-1} = \frac{1}{2}\left(s^L_t + s^L_{t-1}\right)$, $\overline{s}^K_{t/t-1} = 1 - \overline{s}^L_{t/t-1}$ and $s^\iota_{t/t-1}$ represents the share of the input $\iota\,(\iota = K, L)$ (in terms of its compensation) in the value of output (assumed to be measured in terms of value added).[19]

- The growth rate of the multifactor productivity index $MFP^F_{t/t-1}$ captures the proportional change over time of technical progress (Δ refers to discrete changes in percentage with respect to time):

$$\begin{aligned}\Delta MFP^F_{t/t-1} &= \Delta Q^F_{t/t-1} - \Delta I^F_{t/t-1} \\ &= \Delta Q^F_{t/t-1} - \left(\overline{s}^K_{t/t-1} \times \Delta K^F_{t/t-1} + \overline{s}^L_{t/t-1} \times \Delta L^F_{t/t-1}\right) \ ,\end{aligned} \qquad (25)$$

where $Q^F_{t/t-1}$, $K^F_{t/t-1}$ and $L^F_{t/t-1}$ are the Fisher-Ideal indices of output, capital and labour, respectively. In other words, multifactor productivity is simply the growth in output minus the output-share-weighted growth in inputs.

19 $s^L_t = \frac{\text{Labour compensation}}{\text{nominal output}}$ and s^K_t is obtained residually as a result of the constant returns to scale assumption $s^K_t + s^L_t = 1$.

A.4.3 Labour productivity, multifactor productivity and technology

This part develops the basic algebra of productivity accounting and then relates multifactor productivity measures to single-factor (say labour) productivity indices.

Rewrite $\Delta MFP^{F}_{t/t-1}$ as $\left(\overline{s}^{K}_{t,t-1} + \overline{s}^{L}_{t,t-1}\right) \times \Delta MFP^{F}_{t/t-1}$ and collect terms in (25).[20] This yields:

$$\Delta MFP^{F}_{t/t-1} = \overline{s}^{K}_{t/t-1}\left(\Delta Q^{F}_{t/t-1} - \Delta K^{F}_{t/t-1}\right) - \overline{s}^{K}_{t/t-1}\left(\Delta Q^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}\right). \quad (26)$$

Equation (26) has a straightforward interpretation, since the terms between parentheses represent, respectively, the rate of growth of capital productivity and labour productivity. Equation (26) indicates that multifactor productivity is a weighted average of capital productivity and labour productivity, where the weights are respectively output shares of capital and labour. When capital and labour productivity grow at the same rate, because of Hicks neutral technical change, multifactor productivity $\Delta MFP^{F}_{t/t-1}$ is simply the common rate of capital and labour productivity growth.

To provide an interpretation of elements affecting labour productivity, subtract $L^{F}_{t/t-1}$ from the left-hand side and $\left(\overline{s}^{K}_{t/t-1} + \overline{s}^{L}_{t/t-1}\right) \times \Delta L^{F}_{t/t-1}$ from the right-hand side of (25), and then collect terms. This yields:

$$\left(\Delta Q^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}\right) = \Delta MFP^{F}_{t/t-1} + \overline{s}^{K}_{t/t-1}\left(\Delta K^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}\right), \quad (27)$$

which is interpreted as follows. The growth in labour productivity is the sum of two terms: the effects of technological progress $\Delta MFP^{F}_{t/t-1}$ and the capital-share-weighted change in the capital-to-labour ratio. Rapid gains in labour productivity in the 1960s, for example, were attributable partly to neutral technological progress, but also due to the fact that capital per worker increased substantially, i.e. $\Delta K^{F}_{t/t-1} - \Delta L^{F}_{t/t-1} > 0$. Hence, rapid investment in plant and equipment leads to increases in labour productivity.

Note that this growth accounting framework does not explain why $\Delta K^{F}_{t/t-1} - \Delta L^{F}_{t/t-1}$ was positive; that is a different issue. What (27) reveals is that measured labour productivity is positively related to growth in the capital-to-labour ratio and vice versa.

[20] Recall that $\overline{s}^{K}_{t,t-1} + \overline{s}^{L}_{t,t-1} = 1$.

A.5 International comparisons of productivity growth

A.5.1 Introduction

Since its inception, Statistics Canada's productivity program has established the international comparison of productivity performance as one of its priorities.[21] Attempts over the years to improve the comparability between Canada's productivity measures to those of its major trading partners have been undertaken mainly because comparisons provide information on the competitive position of Canada in foreign trade, which has an important influence on the Canadian economy and employment.

Because statistical concepts and methods vary from country to country, international comparisons of statistical data can be misleading. Differences in sources, concepts and methods used in preparing productivity estimates often lead to substantially different results. This is rightfully worrisome for many users who would like to know which ones they should use in their analysis of current economic conditions.

This section deals with the comparability of productivity estimates from various sources with special emphasis on the estimates produced by the OECD, the U.S. Bureau of Labor Statistics and Statistics Canada. The purpose of this section is not so much to suggest the best estimates but merely to emphasize the differences underlying the productivity measures frequently used by analysts.

A.5.1 U.S. Bureau of Labor Statistics (BLS)

Quarterly and annual estimates of labour productivity along with comparable measures of compensation per hour and unit labour costs are published by the BLS. Data are produced for the business sector, the non-farm business sector, non-financial corporations, the manufacturing sector and its durable and non-durable subsectors.

The BLS also produces different sets of annual multifactor productivity estimates. The multifactor productivity indices for the private business sector and the private non-farm business sectors measure the value-added output per unit of combined labour and capital inputs. Multifactor productivity indices for the manufacturing sector and its 20 constituent industries are calculated as output net of intra-industry transactions (sector output) per combined unit of capital services, labour, energy, materials and services (for more details, see BLS 1997).

The differences between the U.S. and Canadian productivity measures are the following:

1. The BLS uses two business sector concepts in its productivity estimates, both of which are different from their Canadian counterparts. Labour productivity estimates cover a business sector that is similar but not identical to the Canadian concept of the business sector. In addition to government, non-profit institutions and the imputed value of owner-occupied dwellings (all of which are excluded from the Canadian business sector), the U.S. business sector, used for labour productivity estimates, also excludes paid employees of private households. On the other hand,

[21] (…) "In order to shed light on changes in the productivity…, the Dominion Bureau of Statistics has also initiated a number of individual industry studies, mainly in the area of manufacturing. The industries to be studied were selected, in co-operation with other government departments, so as to represent a cross-section of manufacturing, including import-competing industries, export industries and typically domestic industries, and with a view to statistical feasibility and international comparability." (Dominion Bureau of Statistics 1965, forward).

U.S. multifactor productivity estimates cover only the private portion of the whole U.S. business sector as they exclude government business enterprises.

These differences are not expected to yield significant differences in terms of the coverage of the business sector between Canada and the U.S. productivity estimates. For example, government business enterprises represent a negligible portion of the U.S. business sector and their importance has been declining since the 1980s in the Canadian business sector. There are other differences, attributable to institutional factors that may, however, introduce significant differences in the coverage of the business sector in Canada and the United States. Health industries, which are part of the business sector in the United States and the government sector in Canada, are a case in point.

2. Comparisons of GDP estimates between Canada and the United States have been affected by recent changes in the definitions and the statistical methods that were incorporated into the U.S. National Accounts with the completion of their 1999 historical revisions. In the United States, two changes have been made (Parker and Grimm, 2000) to the GDP estimates. First, the method to calculate consumer price changes has been altered. Second, all software expenditures are now counted as an investment.

3. The BLS uses the Fisher Ideal index of real output for both labour and multifactor productivity indices, as does Statistics Canada.

4. The BLS uses the concept of value added only for major sectors' estimates of labour productivity (business sector and non-farm business sector) and multifactor productivity (private business sector, private non-farm business and manufacturing sector). Statistics Canada uses the concept of value added for both industries and sectors' labour productivity and multifactor productivity estimates.

   The BLS also uses the concept of sectoral output (gross output net of intra-industry transactions) for

   - labour productivity estimates of the manufacturing sector, its durable and non-durables components, its three- and four-digit industries; and,

   - multifactor productivity estimates of the manufacturing sector, its 20 two-digit industries and the 9 three- and four-digit industries that are produced. While Statistics Canada also produces comparable estimates to facilitate Canada-United States comparison of multifactor productivity, it also produces estimates of multifactor productivity based on the concept of gross output.

5. The BLS, much like Statistics Canada, makes use of the concept of hours worked.[22] Labour productivity estimates produced by Statistics Canada and the BLS both measure labour as a direct summation of hours at work. Similarly, multifactor productivity indices produced by the BLS for manufacturing industries use the same concept of labour as the labour productivity estimates.

[22] For hours worked, the BLS estimates are benchmarked on establishment surveys rather than household surveys. The establishment surveys are themselves benchmarked on administrative data from state unemployment insurance programs (Farmer and Searson 1995). Statistics Canada estimates are taken primarily but not exclusively from household surveys.

The BLS makes adjustment for labour quality only to its estimates of multifactor productivity based on value added for the private business sector and the non-farm private business sector. In this instance, the hours at work for about one thousand categories of workers are classified by their educational attainment and work experience and are aggregated using an annually chained Törnqvist index. The aggregate growth rate of labour input is therefore a weighted average of the growth rates of each type of worker where the weight assigned to a type of worker is its share of total labour compensation. Because their labour input includes labour quality changes, the BLS measures of labour and productivity are affected by these quality changes.

By contrast, Statistics Canada does not make this direct correction for labour quality. However, its method of deriving Fisher indices at the levels of sub-sectors and the business sector partially captures the adjustment of labour quality. The rate of change in hours worked by each industry is aggregated to the subsector (or sector) level using each industry's share in total labour compensation as weights. These weights will be large for industries that pay above-average wages and small for those that do not. If industries with higher wages have been growing more rapidly, this weighting system will decrease estimates of multifactor productivity relative to alternative aggregation schemes that simply take an unweighted average of the growth rates of all industries.

6. Conceptual differences between Statistics Canada and the BLS in the measurement of capital input are even more important than in the case of labour input. These differences arise from the coverage of capital and the way that detailed data on investment are aggregated by vintage and by asset type.

BLS includes in its concept of capital, machinery and equipment, residential and non-residential structures, land and inventories at a fairly detailed level by asset type. By contrast, mainly because of paucity in the data, Statistics Canada's productivity program does not exploit the various asset types on residential and non-residential capital stock currently available from the Investment and Capital Stock Division, nor does it make use of land and inventories in the construction of the capital stock.[23]

BLS's aggregation scheme is based on the 'relative efficiency' for aggregation by vintages and 'rental prices' for the aggregation of different types of assets. The BLS adopts 'age/efficiency' functions that decline gradually during the first few years of an asset's life, and then more rapidly as the asset ages (a concave efficiency schedule).[24] By contrast, Statistics Canada uses a geometric efficiency and

[23] Three major assets are currently available for non-residential capital stock: machinery and equipment, buildings, and engineering construction. For residential capital stock, Statistics Canada currently produces data for the following assets: singles, multiples, mobiles and cottages.

[24] BLS uses a 'hyperbolic' formula to represent the services, s_τ of a τ old asset:

$$\begin{cases} s_\tau = \dfrac{(L-\tau)}{(L-\beta\tau)} & for\ \tau < L \\ s_\tau = 0 & for\ \tau > L, \end{cases}$$

where L is asset's service life, and β is a 'shape' parameter. For $\beta = 1$, this formula yields a gross stock; for $\beta = 0$, it yields a straight line depreciation pattern and for $0 < \beta < 1$, the function declines slowly at first, and then more quickly later. BLS assumes $\beta = 0.5$ for equipment and $\beta = 0.75$ for structures. The formula was implemented assuming the U.S. Bureau of Economic Analysis' service life estimates and also assuming a discard process similar to the one used by BEA.

depreciation pattern. These differences have relatively little effect on cross-country comparisons.

As for the measurement of capital services derived from the capital stock, the BLS applies the rental price and Törnqvist aggregation techniques to detailed categories of asset types. The BLS uses a Törnqvist aggregation with rental prices formulated from Hall-Jorgenson-type tax parameters and a Jorgenson-Griliches type of internal rate of return computed using property income data from the National Income and Product Accounts.[25] In contrast, Statistics Canada sums the three components of capital stock (engineering construction, buildings, and machinery and equipment) for each industry. A Fisher index of capital input is constructed at a higher level of aggregation using capital compensation and capital stock. This methodology implicitly assumes that the capital services yielded by these three assets are equal per dollar of capital stock.

While the BLS still aggregates inputs for its multifactor productivity measures using a Törnqvist chain index, Statistics Canada has switched to the Fisher Ideal index.

A.5.3 Organisation for Economic Co-operation and Development (OECD)

The OECD publishes two sets of estimates that sometimes conflict with one another. One set is produced by the OECD Secretariat and the other by the OECD Statistics Directorate. Both estimates use imperfect measures of inputs because they are interested in cross-country comparisons and cannot get data from some countries that are required for the most precise estimates. By choosing the lowest common denominator available, they provide inaccurate estimates of the true Canadian productivity growth.

Both OECD groups use employment rather than hours-worked to calculate their estimates. This biases the Canadian results downwards.[26]

Equally important, both groups use gross and not net capital stock. It is well recognized that useful capital is net capital. This is the depreciated capital that a firm has available to it. Gross capital stock is the value of capital that was originally purchased and takes no account of the fall in value of capital that occurs over time from use of the capital in production.

Both OECD groups also incorporate another problem. Labour and capital shares of output are needed as weights for the calculation of multifactor productivity. The OECD weights are constant and do not come from Canadian data; they appear to be OECD members' averages.

[25] This implies that property income of industry i in year t is equal to the weighted sum of capital stock, $Y_{i,t} = \sum_j u_{j,i,t} K_{j,i,t} \equiv \sum_j \left(r_{i,t} + \delta_{j,i} + g_{j,i,t} \right) K_{j,i,t}$, where $Y_{i,t}$ is property income assumed to be the residual derived by subtracting labour costs from nominal value added; $K_{j,i,t}$ is the capital stock for the asset j and $u_{j,i,t}$ is the user cost of capital. Data on depreciation rate δ and the capital gain rate g are usually available, but the internal rate of return r is endogenous.

[26] See Chapter 3, "The Precision of Productivity Measures."

In addition to the above problems, the estimate of the OECD Secretariat has three problems:

- First, its measures of outputs and inputs are incompatible. Its measure of output includes owner-occupied dwellings and commercial real estate. But its measure of capital stock does not include the capital that is used for either purpose.

- Second, the measure of inputs and outputs is calculated without taking into account the underlying production structure of the economy. In other words, these estimates are calculated only at the aggregate level and suffer from the type of aggregation bias that was described above.

- Third, its measure of capital stock has been calculated arbitrarily without adequately taking into account Canadian experience. The OECD Secretariat uses an investment series taken from the National Accounts that is not used for the Canadian productivity estimates and ignores the work that has been done on depreciation and discard rates by Statistics Canada's Investment and Capital Stock series.

The OECD Statistics Directorate has created the International Sectoral Data Base (ISDB), which combines a range of data series related primarily to sectoral and industrial value added and their corresponding primary factor inputs (real GDP) used in 14 OECD member countries (OECD 1999). Based on comparable information drawn from sources released by national and international statistical agencies, the database constitutes an important basis for cross-country studies of productivity performance. Therefore, the productivity estimate of the Statistics Directorate follows procedures that are closer to those which have gained international acceptance.

The productivity estimates produced by the ISDB for the 1970 to 1997 period deals with the business sector as a whole as well as with 30 industry groupings covering all industries of 15 member countries. This source is extensively used in the international comparisons of productivity performance.

There are, however, differences between the methodology used by Statistics Canada and that of the ISDB that limit the extent to which results from these two sources may be compared:

- First, the ISDB uses a slightly different definition of the business sector. They include residential housing in their estimates of output and capital stock; Statistics Canada excludes this sector because labour inputs are missing.

- Second, the ISDB starts with individual industry data and aggregates it. However, their aggregation technique uses a Laspeyres weight for only the output, which changes every five years—the same procedure used by the National Accounts of Statistics Canada to produce GDP data. Statistics Canada productivity measures uses an annual Fisher-chained index that updates changes more frequently and is more appropriate for those industries that are experiencing rapid price changes.

- Third, the ISDB does not make any attempt to weight data from underlying industries.

- Fourth, the ISDB uses an index for capital stock that is incompatible with their output index. They choose to use a measure of capital stock which, when rebased, changes all previous growth rates. They use an index of output that does not do so. In contrast, Statistics Canada uses individual industry series for both output and capital whose past growth rates are not changed when rebasing occurs.

Despite these differences, the ISDB estimate is conceptually closer to that of Statistics Canada than that of the OECD Secretariat. At issue is the extent to which the major difference—choice of employment rather than hours worked and use of an inappropriate capital stock—can account for most of the difference between the two series.[27]

Replacing hours worked by employment accounts for most of the difference in the two series. Adding the additional change of gross rather than net capital stock leaves very little difference between the cumulative growth in the two series, despite the other differences that are still embedded in the two estimates. We conclude then that the under estimation of the Canadian productivity performance that has been produced by the Statistics Directorate is almost entirely attributable to their use of these crude measures of inputs.

A.6 Caveats

Measures of labour productivity, multifactor productivity and related measures of costs are useful in investigating the performance of Canadian industries. However, certain characteristics of the productivity and related cost data should be recognized in order to apply them appropriately to specific situations.

First, only the productivity of the business sector is measured. Because of conceptual difficulties, measures of productivity are not available for sectors of the economy, such as government, whose goods and services are not priced by the market.

Second, in several sectors where output is difficult to define, productivity measures are correspondingly weak. Examples are the business services industry, the construction industry and the financial services sector, where output is often an imputed value of labour and other inputs. Thus, the productivity and costs measures for these sectors should be interpreted with caution.

Third, the capital input used in the multifactor productivity framework does not account for land, inventories and natural resources stock, public capital stock and research and development (R&D). Some experimental studies have concluded that natural capital stock, public capital and R&D contribute significantly to multifactor productivity growth.[28] However, these types of inputs pose important challenges in terms of measurement of the quantities and price of services. Nonetheless, as part of an effort to improve the coverage of capital and, accordingly, to increase the comparability between Canadian and U.S. productivity measures, the productivity program has given a priority to estimating land and inventories.

Fourth, measures of productivity account only for resources used in the production process. Unemployed resources available in the economy, which indicate the extent to which the economy is close to its potential capacity, are therefore excluded from the productivity estimates. Nonetheless, comparisons of labour productivity growth and the growth of GDP per capita help to indicate the consequences of not fully employing all labour resources.[29]

Fifth, resources engaged in the production process may not be fully employed, as is often the case in economic downturns. Labour hoarding is a classical example: in response to decreasing demand for its product, an industry may not lay off its employees

[27] See Chapter 3, "The Precision of Productivity Measures."
[28] See Harchaoui (1997), Diaz and Harchaoui (1997) and Mamuneas and Nadiri (1996).
[29] See Chapter 4 on the Canada–United States comparison for a discussion of these issues.

for various reasons such as separation costs and the cost of training new employees should operations expand later on.

A partial adjustment is made to take into account the capacity utilization rate of capital by using the compensation of capital rather than the user cost of capital (Berndt and Fuss 1986). However, at best, this approach only partially dampens the cyclical fluctuations of the productivity growth rates. Since the cyclical fluctuations generally shown by the standard productivity growth measures are often used to make inferences about long-term economic performance, users should be cautious about inferring long-run trends from changes on a yearly basis. To reduce the influence of the cycle on economic performance, users are encouraged to consider a peak-to-peak or a trough-to-trough analysis of productivity growth rates.

A.7 Concluding remarks

This appendix has discussed the development of the Statistics Canada productivity measures program produced for the Canadian business sector and its major constituents (subsectors and industries). It has touched on advances in the literature on productivity measurement and described how these advances have led Statistics Canada to improve the methods it uses and to develop new data series consistent with these advances.

Some further refinements are presently being explored. These advances deal with the quality measurement of the inputs and a broader coverage for the concept of capital that includes land, inventories and exhaustible resources stocks. There are also new lines of research in the productivity front that are worth investigating in the near future. Among these are studies using firm or establishment level data,[30] studies that relax the assumption of constant returns to scale underlying the multifactor productivity framework,[31] and studies designed to expand the scope of productivity measurement to include environmental considerations.

References

Berndt, E.R. and M.A. Fuss 1986. "Productivity measurement with adjustments for variations in capacity utilization and other forms of temporary equilibrium." *Journal of Econometrics.* 33: 7-29.

Cas, A. and T.K. Rymes. 1991. *On Concepts and Measures of Multifactor Productivity.* Cambridge: Cambridge University Press.

Diaz, A. and T.M. Harchaoui. 1997. "Accounting for Exhaustible Resources in the Canadian System of National Accounts: Flows, Stocks and Productivity Measures." *Review of Income and Wealth.* 43: 465-485.

Diewert, W. E. 1976. "Exact and Superlative Index Numbers." *Journal of Econometrics.* 4: 115-145.

Domar, E.D. 1961. "On the Measurement of Technical Change." *Economic Journal. 71*, 204: 709-729.

[30] See Chapter 5 in this publication.
[31] See Chapter 8 in this publication.

Dominion Bureau of Statistics. 1965. *Indexes of Output Per Person Employed and Per Man-Hour in Canada, Commercial Nonagricultural Industries, 1947-63.* Statistics Canada Catalogue no.14-501. Ottawa: Minister responsible for Statistics Canada. Occasional.

Durand R. 1996. "Canadian Input-output-based Multifactor Productivity Accounts." *Economic Systems Research.* 8: 367-389.

———. 1994. "Le programme de productivité multifactorielle de Statistique Canada." *L'actualité économique.* 69: 313-330.

Farmer, T.E. and M.A. Searson. 1995. "Use of Administrative Records in the Bureau of Labor Statistics." *Covered Employment and Wages (Es-202) Program.* 1995 Bureau of the Census Annual Research Conference. U.S. Bureau of Labor Statistics. Washington: The U.S. Government Printing Office.

Gollop, F.M. 1979. "Accounting for Intermediate Input: The Link Between Sectoral and Aggregate Measures of Productivity." *Measurement and Interpretation of Productivity.* Washington: National Academy of Sciences. *318-333.*

Griliches, Z. 1980. "R&D and the Productivity Slowdown." *American Economic Review.* 70: 343-348.

Harchaoui, T.M. 1997. "Le capital public au Canada: évolution historique et externalités." *L'économétrie appliquée, L'actualité économique.* C.Gouriéroux and C. Montmarquette (eds). 73: 395-421.

Jackson, C. 1996. "The Effect of Rebasing on GDP." *National Economic and Financial Accounts.* Second Quarter. Statistics Canada Catalogue no. 13-001-XPB. Ottawa: Minister responsible for Statistics Canada.

Jorgenson, D.W. 1990. "Productivity and Economic Growth." *Fifty Years of Economic Measurement.* E. R. Berndt and J.E. Triplett (eds). NBER. *Studies in Income and Wealth.* 54: 19-118.

Jorgenson, D.W. and Z. Griliches. 1967. "The Explanation of Productivity Change." *Review of Economic Studies.* 99: 249-283.

Jorgenson, D.W. and K.-Y. Yun. 1991. *Tax Reform and the Cost of Capital.* New York: Oxford University Press.

Lal, K. 1998. *The 1997 Historical Revision of the Canadian System of National Accounts: Records of Changes in Classification of Sectors and Transactions, Concepts and Methodology.* Statistics Canada Catalogue no. 13N0005XPE. March.Ottawa: Minister responsible for Statistics Canada.

Mamuneas, T and I. Nadiri. 1996. "Public R&D Policies and Cost Behavior of the U.S. Manufacturing Industries." *Journal of Public Economics.* 63: 57-81.

Mirotchie, M. 1996. "Methodology Used to Produce Advance Estimates of Multifactor Productivity Indices for the Canadian Aggregate Business Sector." *Aggregate Productivity Measures.* Statistics Canada Catalogue no.15-204-XPE. Ottawa: Minister responsible for Statistics Canada.

Organisation for Economic Co-operation and Development (OECD). 1999. *International Sectoral Database 98, User's Guide.* Statistics Directorate. Paris: OECD.

Parker, R. and B. Grimm. 2000. "Software Prices and Real Output: Recent Developments at the Bureau of Economic Analysis." Paper presented at the National Bureau of Economic Research on Technological Change and Productivity Measurement. April 17. Bureau of Economic Analysis. U.S. Department of Commerce.

Rees, A. 1980. "Improving Productivity Measurement." *American Economic Review.* 70: 340-342.

Rymes, T.K. 1972. "The Measurement of Capital and Total Factor Productivity in the Context of the Cambridge Theory of Capital." *Review of Income and Wealth.* 18: 79-108.

Solow, R.M. 1958. "'Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* 39: 312-320.

Statistics Canada. 1975. *A Guide to the National Income and Expenditure Accounts: Definitions,Concepts, Sources and Methods.* Catalogue no. 13-549E, vol.3. National Income and Expenditure Accounts. Ottawa: Minister responsible for Statistics Canada. Occasional.

———. 1999. *Canadian Net Capital Stock Estimates and Depreciation Profiles: A Comparison Between the Existing Series and a Test Series Using the U.S. (BEA) Methodology.* March. Investment and Capital Stock Division.Ottawa.

U.S. Bureau of Labor Statistics. 1997. *BLS Handbook of Methods.* Bulletin 2490. Washington: The U.S. Government Printing Office.

Wolfe, E.N. 1991. "Dynamic of Growth in Input-output Analysis." *Technology and Productivity, the Challenge for Economic Policy.* Paris: OECD.565-574.

Appendix 2 – Industrial Detail for Productivity Measures and Related Variables

Desmond Beckstead and Jean-Pierre Maynard

The productivity estimates are produced only for input–output accounts (IOA) business sector industries, as defined in Appendix 1 of this publication. The industrial detail within the business sector is based on Statistics Canada's industry classification systems. Since 1981, the system in use has been the 1980 Standard Industrial Classification (SIC).[1] Before this date, the 1960 SIC and 1970 SIC were used. In the IOA, the levels of SIC industries are chosen so as to provide the most detail possible in order to maximize continuity with the previous SIC classifications used. However, the greatest level of detail that is available over time occurs at the L level of aggregation. Data are available at the L-level aggregation of SIC industries for the entire time period from 1961 to the present.

Table A2.1 shows how much industrial detail is provided in the IOA at the three basic levels of productivity output: L (link), M (medium) and S (small). The L-level provides the most detail, and the S-level the least. Each category is defined by the type(s) of establishments involved.

- The business industries, are composed of commercial establishments. These establishments operate on a commercial basis–they sell their goods and services at a price that is designed to cover costs and yield a profit. Included in the business industries are government business enterprises: those "government activities that are conducted on an essentially commercial basis—where the operation is designed to be self-sustaining and where a price is set for the goods and services that is calculated to cover costs" (Statistics Canada 1975).

- The dummy industries are used to differentiate between the various types of markups that are applied to commodities as they are passed from the original producer to the final consumer, even though the goods remain in exactly the same physical condition. For example, the value of the wholesale and retail margins is the difference between the sales and cost of the commodities purchased for resale.

- Services provided by private non-commercial institutions and most services provided by governments are not bought and sold in the market but are rendered to the community without charge and are defined as non-business industries. The non-business industries indicated in Table A2.1 are composed of only non-commercial establishments.

[1] In the near future, all the industry classification in the Input-Output Accounts will be related to the North American Industry Classification System (NAICS).

- Some commercial establishments reside in industries along with non-commercial establishments. These industries are referred to in Table A2.1 as business industries composed of commercial and non-commercial establishments. In industries such as health and education, the non-commercial establishments dominate, while in others (e.g., transportation, radio and television), commercial establishments are the major players.

Table A2.1 Industries at the L , M and S levels

Industrial components	Number of industries	
	Commercial establishments	Non-Commercial establishments
Business industries	L=124 M=29 S=2	–
Dummy industries	L=7 M=3 S=3	
Non-business industries	–	L=4 M=1 S=0
Business industries composed of commercial and non-commercial establishments	L=32 M=25 S=16	
Total economy	L=167 M=58 S=21	

The industrial coverage of the aggregates used in the productivity accounts matches that of the IOA with only one exception, owner occupied dwellings (industry L 136 in Table A2.2 of this appendix). This industry is excluded from productivity analysis because data on labour inputs are not available. This exception aside, labour productivity and unit labour costs are evaluated for business sector L-level industries. Other related variables, such as employment, hours worked and labour compensation, are also evaluated for the business sector industries and for some non-commercial activities.

For the purpose of deriving multifactor productivity growth rates, the inputs of goods and services were taken from the input–output tables at the most detailed level of the L-level industries (167 industries). However, it was not possible to use the inputs or outputs by industry at the L-level because capital stock series can only be produced at a slightly higher level of detail. Thus for the multifactor productivity measures, input–output tables have been aggregated to a special level of aggregation, identified as P, which consists of 123 business sector industries.

Table A2.2 below shows the concordance between the L-level, the 1980 SIC, the M-level and the S-level industries of the IOA, including the special aggregation (P) used for multifactor productivity estimates. The industry names are given for the L-level industries.

Table A2.3 presents the concordance between the L-, M- and S-level industries for all the relevant non-business industries for which we publish employment, hours worked and labour compensation estimates.

Table A2.4 presents all the special aggregations used either for the multifactor productivity or labour productivity estimates. There are 12 special aggregations, including the total business sector, the business sector excluding agriculture, and business sector—goods.

Table A2.2 Concordance between L industries and 1980 SIC, P, M and S industries for the business sector

L	Industry title for the L level	1980 SIC	P	M	S
1	Agricultural and related service	011-023	1	1	1
2	Fishing and trapping	031-033	2	2	2
3	Logging and forestry	041, 051	3	3	3
4	Gold mines	0611	4	4	4
5	Other metal mines	0612-0616, 0619	5	4	4
6	Iron mines	0617	6	4	4
7	Asbestos mines	0621	7	4	4
8	Other non-metal mines (except coal)	0622-0624, 0629	8	4	4
9	Salt mines	0625	9	4	4
10	Coal mines	063	10	4	4
11	Crude petroleum and natural gas	071	11	5	4
12	Quarry and sand pit	081,082	12	6	4
13	Service incidental to mineral extraction	091,092	13	7	4
14	Meat and meat products (except poultry)	1011	14	8	5
15	Poultry products	1012	14	8	5
16	Fish products	102	15	8	5
17	Fruit and vegetable	103	16	8	5
18	Dairy products	104	17	8	5
19	Miscellaneous food product	1051,1052, 1082,1083, 109	18	8	5
20	Feed	1053	18	8	5
21	Vegetable oil mills (except corn oil)	106	19	8	5
22	Biscuit	1071	20	8	5
23	Bread and other bakery products	1072	20	8	5
24	Cane and beet sugar	1081	18	8	5
25	Soft drink	111	21	9	5
26	Distillery products	112	22	9	5
27	Brewery products	113	23	9	5
28	Wine	114	24	9	5
29	Tobacco products	121,122	25	10	5
30	Rubber products	151-159	26	11	5
31	Plastic products	161-169	27	12	5
32	Leather tanneries	1711	28	13	5
33	Footwear	1712	28	13	5
34	Miscellaneous leather and allied products	1713,1719	28	13	5
35	Man-made fibre yarn and woven cloth	181,1829	29	14	5
36	Wool yarn and woven cloth	1821	29	14	5
37	Broad knitted fabric	183	30	14	5
38	Miscellaneous textile products	193, 199	31	15	5
39	Carpet, mat and rug	192	32	15	5
40	Clothing excluding hosiery	243-245, 2491-2493,2495-2499	33	16	5
41	Hosiery	2494	33	16	5
42	Sawmill, planing mill and shingle mill products	251	34	17	5
43	Veneer and plywood	252	35	17	5
44	Sash, door and other millwork	254	36	17	5
45	Wooden box and coffin	256,258	37	17	5
46	Other wood	259	38	17	5
47	Household furniture	261	39	18	5
48	Office furniture	264	40	18	5
49	Other furniture and fixture	269	41	18	5
50	Pulp and paper	271	42	19	5
51	Asphalt roofing	271	43	19	5
52	Paper box and bag	273	44	19	5
53	Other converted paper products	279	45	19	5
54	Printing and publishing	281,283-284	46	20	5
55	Platemaking, typesetting and bindery	282	47	20	5
56	Primary steel	291	48	21	5
57	Steel pipe and tube	292	49	21	5
58	Iron foundries	294	50	21	5
59	Non-ferrous metal smelting and refining	295	51	21	5
60	Aluminum rolling, casting and extruding	296	52	21	5
61	Copper and alloy rolling, casting and extruding	297	53	21	5
62	Other rolled, cast and extruded non-ferrous metal products	299	54	21	5

Table A2.2 Concordance between L industries and 1980 SIC, P, M and S industries for the business sector – Continued

L	Industry title for the L level	1980 SIC	P	M	S
63	Power boiler and structural metal	301-302	55	22	5
64	Ornamental and architectural metal products	303	56	22	5
65	Stamped, pressed and coated metal products	304	57	22	5
66	Wire and wire products	305	58	22	5
67	Hardware, tool and cutlery	306	59	22	5
68	Heating equipment	307	60	22	5
69	Machine shop	308	61	22	5
70	Other metal fabricating	309	62	22	5
71	Agricultural implement	311	63	23	5
72	Commercial refrigeration and air conditioning equipment	312	64	23	5
73	Other machinery and equipment	319	65	23	5
74	Aircraft and aircraft parts	321	66	24	5
75	Motor vehicle	323	67	24	5
76	Truck and bus body and trailer	324	68	24	5
77	Motor vehicle parts and accessories	325	69	24	5
78	Railroad rolling stock	326	70	24	5
79	Shipbuilding and repair	327	71	24	5
80	Miscellaneous transportation equipment	328-329	72	24	5
81	Small electrical appliance	331	73	25	5
82	Major appliances (electric and non-electric)	332	74	25	5
83	Other electrical and electronic product	333, 337, 3392, 3399	75	25	5
84	Record player, radio and television receiver	334	76	25	5
85	Communication and other electronic equipment	335	77	25	5
86	Office, store and business machine	336	78	25	5
87	Communication and energy wire and cable	338	79	25	5
88	Battery	3391		25	5
89	Clay products	351	80	26	5
90	Hydraulic cement	352	81	26	5
91	Concrete products	354	82	26	5
92	Ready-mix concrete	355	83	26	5
93	Glass and glass products	356	84	26	5
94	Miscellaneous non-metallic mineral products	357-359	85	26	5
95	Refined petroleum and coal products	361, 369	86	27	5
96	Industrial chemicals n.e.c.	371	87	28	5
97	Chemical products n.e.c.	372, 379	88	28	5
98	Plastic and synthetic resin	373	89	28	5
99	Pharmaceutical and medicine	374	90	28	5
100	Paint and varnish	375	91	28	5
101	Soap and cleaning compounds	376	92	28	5
102	Toilet preparations	377	93	28	5
103	Other manufacturing	391, 3991, 3992, 3994,3999	94	29	5
104	Jewellery and precious metal	392	95	29	5
105	Sporting goods and toy	393	96	29	5
106	Sign and display	397	97	29	5
107	Floor tile, linoleum and coated fabric	3993	94	29	5
108	Repair construction	401-449	98	30	6
109	Residential construction	401-449	98	30	6
110	Non-residential building construction	401-449	98	30	6
111	Road, highway and airport runway construction	401-449	98	30	6
112	Gas and oil facility construction	401-449	98	30	6
113	Electric power, dams and irrigation construction	401-449	98	30	6
114	Railway, and telecommunication construction	401-449	98	30	6
115	Other engineering construction	401-449	98	30	6
116	Construction, other activities	401-449	98	30	6
117	Air transport and related service	451,452	99	31	7
118	Railway transport and related service	453	100	31	7
119	Water transport and related services	454,455	101	31	7
120	Truck transport	456	102	31	7
121	Urban transit systems	4571	103	31	7
122	Interurban and rural transit systems	4572	103	31	7
123	Miscellaneous transport services	4573, 4575, 458, 459	103	31	7

Table A2.2 Concordance between L industries and 1980 SIC, P, M and S industries for the business sector – Concluded

L	Industry title for the L level	1980 SIC	P	M	S
124	Pipeline transport	461	104	32	7
125	Storage and warehousing	471, 479	105	33	7
126	Telecommunication broadcasting	481	106	34	8
127	Telecommunication carriers	482-483	107	34	8
128	Postal and courier service	484	108	34	8
129	Electric power systems	491	109	35	8
130	Gas distribution systems	492	110	35	8
131	Water systems and other utility n.e.c.	493, 499	111	35	8
132	Wholesale trade	501-599	112	36	9
133	Retail trade	601-692	113	37	10
134	Finance and real estate	701-709, 711-729, 7511, 7512, 759	114	38	11
135	Insurance	731-733	115	39	11
136	Owner occupied dwellings	7513[2]	116	40	11
137	Other business services	771, 772, 777, 779	117	41	12
138	Professional business services	773, 775, 776	117	41	12
139	Advertising services	774	117	41	12
140	Educational service , private	851, 852, 854-859	118	42	13
141	Other health and social service	862, 863, 865-869	119	43	14
142	Accommodation, food and beverage service	911-914, 921, 922	120	44	15
143	Motion picture and video	961-962	121	45	16
144	Other amusement and recreational services	963-969	121	45	16
145	Other personal service	971, 973, 974-979	122	46	16
146	Laundries and cleaners	972	122	46	16
147	Membership organizations (excluding religion) and other services	982-986, 991-999	123	47	16

[2] This is a code specific to the Input-Output Accounts. It is used to express the opportunity cost of owners that occupied their own residence.

Table A2.3 Concordance between the L level industries and the 1980 SIC for the non-business sector industries for which employment and hours worked are provided

L	Industry title	1980 SIC	M	S
1	Service incidental to agriculture	021-023	1	1
2	Fishing and trapping	031-033	2	2
3	Forestry services	051	3	3
103	Miscellaneous manufactured products n.e.c.	3999	29	5
117	Air transport and related service	451-452	31	7
119	Water transport and related services	454-455	31	7
121	Urban transit systems	4571	31	7
123	Other service incidental to transportation	459	31	7
126	Radio and television broadcasting	4811-4813	34	8
131	Water systems and other utility n.e.c.	493, 499	35	8
132	Wholesale trade	501-599	36	9
133	Retail trade	601-692	37	10
134	Finance and real estate	711-729, 741-749, 751, 759	38	11
135	Insurance	731-733	39	11
137	Other business services	771, 777, 779	41	12
138	Professional business services	773, 775, 776,	41	12
140	Educational service , public	851, 852, 854-859	42	13
141	Other health and social service	862-869	43	14
142	Accommodation, food and beverage services	911-914, 921, 922	44	15
143	Motion picture and video	961, 962	45	16
144	Other amusement and recreational services	963-969	45	16
145	Other personal service	971, 973, 974, 979	46	16
147	Membership organizations (excluding religion) and other services	982-986, 991-999	47	16
155	N.B. – P. Religious organizations	981	47	16
160	N.B. – G. Hospitals	861	43	14
162	N.B. – G. University education	853	42	13
164	N.B. – G. Defence services	811	59	22
168	N.B. – G. Federal government service (excluding defence)	812-817	59	22
169	N.B. – G. Provincial and territorial government service	822-827	60	22
170	N.B. – G. Municipal government service	832-837	61	22

Notes: NB - P: non-commercial - private sector, NB - G: non-commercial - government sector, nec: not elsewhere classified

Table A2.4 Special aggregations for multifactor productivity, labour productivity and related variables			
Codes	**Industry Groupings**	**P Codes**	**L Codes**
1	Total economy	NA	B & NB (1-135, 137-170)
2	Business sector	1-115, 117-123	1-135, 137-147
3	Business sector - Goods	1-98, 109-111	1-116, 129-131
4	Business sector - Services	99-108, 112-115, 117-123	117-128,132-135, 137-147
5	Non business sector industries	NA	NB (1-3, 103, 117, 119, 121, 123, 126, 131-135, 137, 138, 140-145, 147, 155, 160, 162, 164, 168-170)
6	Non-business sector – Goods	NA	NB (1-3,103, 131)
7	Non-business sector – Services	NA	NB (117, 119, 121, 123, 126, 132-135, 137, 138, 140-145, 147, 155, 160, 162, 164, 168-170)
8	Total economy – goods	NA	B & NB (1-116, 129-131)
9	Total economy – services	NA	B & NB (117-128,132-135, 137-147, 155, 160, 162, 164, 168-170)
10	Business sector excluding Agriculture	2 to 123 excluding 116	2-135, 137-147
11	Non-durables manufacturing industries	14-33, 42-47, 86-93	14-41, 50-55, 95-102
12	Durables – manufacturing industries	34-41, 48-85, 94-97	42-49, 56-94, 103-107

Notes: B: business sector, NB: non-commercial sector, NA: not applicable

Reference:

Statistics Canada. 1975. *A guide to the National Income and Expenditure Accounts: Definitions, Concepts, Sources and Methods*. Catalogue no. 13-549E. 3. System of National Accounts. Ottawa: Minister responsible for Statistics Canada. Occasional.

Appendix 3 – Quality Rating of Productivity Estimates and Related Data

This appendix can be found electronically on our website at :

www.statcan.ca/english/concepts/method.htm

Appendix 4 – Productivity and Related Data in CANSIM

Multifactor productivity	Indices since 1961	CANSIM matrices
Gross output		9456
Gross output excluding intra-industry		9457
Real value added and related data		9458

Labour productivity	Indices since 1946	
Real gross domestic product		9475
Total number of jobs		9476
Annual average number of hours worked for all jobs		9477
Hours worked for all jobs		9478
Total compensation for all jobs		9479
Real gross domestic product per hour worked for all jobs		9480
Total compensation per job		9481
Total compensation per hour worked for all jobs		9482
Unit labour costs		9483

Labour productivity	Absolute values since 1961	
Real gross domestic product		9460
Total number of jobs		9461
Average number of hours worked per year for all jobs		9462
Number of hours worked for all jobs		9463
Total compensation for all jobs		9464
Real gross domestic product per hour worked for all jobs		9465
Total compensation per job		9466
Total compensation per hour worked for all jobs		9467
Unit labour cost		9468
Number of employee jobs		9469
Average number of hours worked per year for employee jobs		9470
Number of hours worked for employee jobs		9471
Labour income per hour worked of employee jobs		9472
Total number of jobs		9473
Hours worked for all jobs		9474

Appendix 5 – Estimates of the Sectorial Sources of Economic Growth in Canada, 1961-1999;

The productivity estimates provided in this publication are limited to the business sector of the economy[1] .

This Appendix provides indices and annual growth rates for the multifactor productivity and its components for the business sector and its sub-sectors (business sector goods-producing, business sector services-producing, business sector excluding agriculture and the manufacturing sub-sector). The following components (and derived measures) have been provided for the 1961-1999 period:

1. Output growth rate is measured by the growth rate of real value added
2. The growth rate for capital input
3. The share for capital
4. The capital contribution to output growth is calculated as the product of the (growth rate for) capital input and its share
5. The growth rate for labour input
6. The share for labour
7. The labour contribution to output growth is the product of labour input and its share
8. Multifactor productivity is output growth minus the capital contribution minus the labour contribution
9. A related measure of interest is the growth in the capital/labour ratio – it is given by the capital growth rate minus the labour growth rate.

Multifactor productivity using the value added approach is the difference between the growth rates of output and the growth rate of the combined inputs (labour and capital). In measuring the growth rate of inputs, the growth rate of each input is weighted by its share of output[2] .

[1] Details on what constitutes the business sector are provided in Appendix 2.
[2] See Appendix 1 for more detail.

The indices for the multifactor productivity components can be derived directly from their growth rates. Using the business sector growth rate for real value added from Table 2 and its index from Table 1, the following describes how one can be converted to the other:

- The real value added growth rate for 1962 from Table 2 indicates a 7.1% increase from 1961. That is, an index level of 100 in 1961 for real value added was followed by an index level of 100 * (1 + .071) = 107.1. Once the values are available for all years they can be adjusted to a 1992 base by dividing all by the index level for 1992.

- Table 2 shows that the index values for real value added for 1961 is 32.2 and the index for 1962 is 34.5. The ratio of the index for 1962 to that for 1961 is 34.5 / 32.2 = 1.071; hence the growth rate is this ratio minus one: 1.071 - 1 = .071 or 7.1%.

Table 1. Business sector industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720329	I 720330	I 720331	I 720332	I 720328
1961	32.2	58.4	29.7	45.5	70.2
1962	34.5	60.4	30.4	46.9	73.0
1963	36.5	61.6	31.2	47.9	75.7
1964	39.1	63.9	32.2	49.6	78.3
1965	41.9	66.7	34.1	52.1	80.1
1966	44.9	70.3	36.5	55.2	81.0
1967	45.8	71.1	39.4	57.2	79.7
1968	48.3	70.8	41.6	58.1	82.7
1969	50.8	72.1	43.2	59.6	84.8
1970	51.9	71.6	44.8	60.1	86.0
1971	54.5	72.6	46.3	61.3	88.5
1972	57.8	74.5	47.6	62.9	91.5
1973	62.6	78.3	49.6	65.9	94.8
1974	64.2	81.2	51.9	68.7	93.3
1975	64.4	80.6	54.4	69.6	92.4
1976	68.8	81.3	56.8	71.0	96.7
1977	71.2	81.9	59.3	72.6	98.1
1978	73.7	84.1	61.6	74.8	98.4
1979	76.8	88.1	64.0	78.1	98.2
1980	78.5	89.5	67.8	80.7	97.2
1981	80.7	92.3	73.5	84.9	94.9
1982	77.4	87.3	78.7	84.2	91.7
1983	79.7	86.7	80.5	84.7	94.0
1984	84.7	89.5	81.5	86.7	97.6
1985	89.7	92.8	83.1	89.3	100.5
1986	92.2	95.6	85.1	91.8	100.4
1987	96.5	99.7	87.2	95.1	101.5
1988	101.0	104.6	90.0	99.1	101.9
1989	103.5	107.2	93.6	102.1	101.3
1990	102.9	106.4	97.3	103.1	99.9
1991	99.5	102.0	99.3	101.0	98.5
1992	100.0	100.0	100.0	100.0	100.0
1993	102.9	101.2	101.6	101.3	101.6
1994	108.9	104.6	103.4	104.1	104.7
1995	113.1	106.7	107.6	107.0	105.8
1996	115.7	108.9	111.3	109.8	105.5
1997	121.8	112.1	113.3	112.6	108.4
1998	125.8	115.4	117.3	116.2	108.5
1999	131.8	119.5	120.7	120.0	110.2

Table 2. Breakdown of annual growth in real value added, business sector industries

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ %	Δ %	%	Δ %	Δ %	Δ %
				(2) x (3)			(5) x (6)	(1) - (4) - (7)	(2) - (5)
1962	7.1	2.6	35.3	0.9	3.4	64.7	2.2	4.0	-0.8
1963	5.9	2.5	36.3	0.9	1.9	63.7	1.2	3.7	0.6
1964	7.1	3.3	36.9	1.2	3.7	63.1	2.4	3.5	-0.4
1965	7.2	5.8	36.8	2.1	4.5	63.2	2.8	2.3	1.4
1966	7.0	6.9	36.4	2.5	5.4	63.6	3.4	1.1	1.5
1967	2.1	8.1	35.4	2.9	1.2	64.6	0.8	-1.5	6.9
1968	5.4	5.6	35.2	2.0	-0.4	64.8	-0.3	3.7	6.0
1969	5.1	3.7	35.4	1.3	1.8	64.6	1.2	2.6	1.9
1970	2.2	3.7	35.2	1.3	-0.7	64.8	-0.5	1.3	4.4
1971	5.1	3.4	35.1	1.2	1.4	64.9	0.9	2.9	2.0
1972	6.0	2.8	34.9	1.0	2.5	65.1	1.6	3.4	0.3
1973	8.3	4.1	35.9	1.5	5.1	64.1	3.3	3.6	-1.0
1974	2.6	4.8	37.0	1.8	3.7	63.0	2.3	-1.5	1.1
1975	0.3	4.7	37.0	1.8	-0.7	63.0	-0.4	-1.0	5.4
1976	6.8	4.3	36.3	1.6	0.8	63.7	0.5	4.7	3.5
1977	3.6	4.5	35.9	1.6	0.8	64.1	0.5	1.4	3.7
1978	3.5	3.9	36.6	1.4	2.6	63.4	1.7	0.4	1.3
1979	4.1	3.8	38.3	1.5	4.7	61.7	2.9	-0.2	-0.9
1980	2.3	6.0	39.3	2.4	1.6	60.7	1.0	-1.1	4.4
1981	2.8	8.3	38.8	3.2	3.2	61.2	1.9	-2.4	5.2
1982	-4.1	7.1	37.5	2.7	-5.5	62.5	-3.4	-3.3	12.6
1983	3.0	2.3	38.3	0.9	-0.6	61.7	-0.4	2.4	2.9
1984	6.3	1.2	40.1	0.5	3.2	59.9	1.9	3.9	-1.9
1985	5.9	2.0	40.3	0.8	3.7	59.7	2.2	2.9	-1.7
1986	2.8	2.3	39.3	0.9	3.1	60.7	1.9	0.0	-0.8
1987	4.7	2.5	38.6	1.0	4.3	61.4	2.6	1.1	-1.8
1988	4.6	3.2	38.3	1.2	4.9	61.7	3.0	0.4	-1.7
1989	2.5	4.1	37.4	1.5	2.5	62.6	1.5	-0.6	1.6
1990	-0.5	3.9	36.5	1.4	-0.8	63.5	-0.5	-1.5	4.7
1991	-3.3	2.0	35.0	0.7	-4.1	65.0	-2.7	-1.3	6.2
1992	0.5	0.7	33.9	0.2	-1.9	66.1	-1.3	1.5	2.7
1993	2.9	1.6	34.3	0.6	1.2	65.7	0.8	1.6	0.4
1994	5.8	1.7	36.1	0.6	3.3	63.9	2.1	3.0	-1.6
1995	3.9	4.1	38.1	1.6	2.0	61.9	1.2	1.1	2.1
1996	2.3	3.4	38.9	1.3	2.1	61.1	1.3	-0.3	1.4
1997	5.3	1.8	38.9	0.7	2.9	61.1	1.8	2.8	-1.1
1998	3.3	3.5	38.9	1.4	3.0	61.1	1.8	0.1	0.5
1999	4.8	2.9	38.9	1.1	3.5	61.1	2.2	1.5	-0.7

Table 3. Business sector goods industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720351	I 720352	I 720353	I 720354	I 720350
1961	38.9	84.6	33.9	58.6	65.8
1962	42.8	87.5	34.2	60.0	70.8
1963	45.4	88.6	34.8	60.9	74.1
1964	48.5	91.5	35.8	62.8	76.8
1965	52.4	95.4	38.2	66.0	79.0
1966	55.5	100.4	41.2	70.1	78.9
1967	55.7	99.5	45.3	72.2	76.7
1968	59.3	98.5	48.1	73.3	80.6
1969	62.3	98.9	49.6	74.3	83.6
1970	61.5	96.3	51.5	74.0	82.8
1971	64.7	97.2	53.5	75.4	85.5
1972	67.7	98.2	54.8	76.6	88.2
1973	74.2	103.3	56.7	80.1	92.5
1974	74.3	106.0	59.1	82.7	89.7
1975	72.6	102.2	61.5	82.3	88.0
1976	78.4	103.2	63.8	84.0	93.2
1977	81.5	101.7	66.6	84.7	96.2
1978	83.0	102.7	69.1	86.6	95.9
1979	85.4	106.5	71.3	89.6	95.3
1980	85.8	106.6	75.4	91.9	93.2
1981	87.7	107.7	82.4	96.1	90.9
1982	83.2	98.0	89.4	94.7	87.7
1983	86.1	96.0	92.4	95.1	90.5
1984	92.6	98.0	92.8	96.4	96.0
1985	97.5	100.9	93.1	98.1	99.5
1986	98.2	103.2	93.9	99.7	98.6
1987	102.1	108.0	93.7	102.2	100.1
1988	106.5	114.1	94.4	105.9	100.8
1989	108.4	115.9	97.1	108.1	100.5
1990	106.6	111.8	99.5	106.8	99.9
1991	101.2	103.3	100.2	102.1	99.2
1992	100.0	100.0	100.0	100.0	100.0
1993	103.1	99.6	98.0	98.9	104.2
1994	108.6	103.0	97.3	100.5	107.9
1995	112.6	104.5	100.8	103.0	109.3
1996	115.2	105.9	103.3	104.9	109.8
1997	121.7	109.4	104.2	107.1	113.6
1998	124.2	112.5	106.8	110.0	112.9
1999	129.8	115.7	107.5	112.0	116.0

Table 4. Breakdown of annual growth in real value added, business sector goods industries

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ %	Δ %	%	Δ %	Δ %	Δ %
				(2) x (3)			(5) x (6)	(1) - (4) - (7)	(2) - (5)
1962	10.1	0.8	36.7	0.3	3.4	63.3	2.1	7.7	-2.5
1963	6.2	1.9	37.6	0.7	1.3	62.4	0.8	4.6	0.6
1964	6.8	2.9	37.7	1.1	3.2	62.3	2.0	3.7	-0.3
1965	8.0	6.4	37.2	2.4	4.3	62.8	2.7	2.9	2.1
1966	6.0	7.9	35.4	2.8	5.2	64.6	3.4	-0.2	2.7
1967	0.3	10.1	34.9	3.5	-0.8	65.1	-0.5	-2.6	10.9
1968	6.5	6.1	35.8	2.2	-1.0	64.2	-0.6	4.9	7.1
1969	5.1	3.2	35.2	1.1	0.3	64.8	0.2	3.7	2.9
1970	-1.3	3.7	34.5	1.3	-2.6	65.5	-1.7	-0.8	6.3
1971	5.2	4.0	34.7	1.4	0.9	65.3	0.6	3.2	3.0
1972	4.6	2.4	37.4	0.9	1.0	62.6	0.7	3.1	1.3
1973	9.5	3.6	40.6	1.4	5.3	59.4	3.1	4.9	-1.7
1974	0.2	4.2	40.8	1.7	2.5	59.2	1.5	-3.0	1.6
1975	-2.3	4.1	39.7	1.6	-3.5	60.3	-2.1	-1.8	7.7
1976	8.0	3.7	39.4	1.5	1.0	60.6	0.6	5.9	2.7
1977	4.0	4.4	40.6	1.8	-1.5	59.4	-0.9	3.1	5.8
1978	1.9	3.8	43.1	1.6	1.0	56.9	0.5	-0.3	2.8
1979	2.8	3.1	45.1	1.4	3.7	54.9	2.0	-0.7	-0.6
1980	0.5	5.8	44.4	2.6	0.1	55.6	0.1	-2.1	5.7
1981	2.2	9.3	42.7	4.0	1.0	57.3	0.6	-2.3	8.3
1982	-5.2	8.4	43.5	3.6	-9.0	56.5	-5.1	-3.7	17.4
1983	3.5	3.4	46.3	1.6	-2.1	53.7	-1.1	3.1	5.4
1984	7.5	0.4	47.4	0.2	2.1	52.6	1.1	6.1	-1.7
1985	5.3	0.3	45.4	0.1	3.0	54.6	1.6	3.6	-2.7
1986	0.7	0.9	44.1	0.4	2.2	55.9	1.2	-0.9	-1.3
1987	4.0	-0.2	44.1	-0.1	4.7	55.9	2.6	1.4	-5.0
1988	4.3	0.8	43.0	0.3	5.6	57.0	3.2	0.7	-4.9
1989	1.8	2.9	41.8	1.2	1.6	58.2	0.9	-0.3	1.3
1990	-1.7	2.4	39.8	1.0	-3.5	60.2	-2.1	-0.5	5.9
1991	-5.0	0.8	38.0	0.3	-7.6	62.0	-4.7	-0.6	8.4
1992	-1.2	-0.2	39.0	-0.1	-3.2	61.0	-1.9	0.8	2.9
1993	3.1	-2.0	41.9	-0.8	-0.4	58.1	-0.2	4.2	-1.6
1994	5.3	-0.7	44.9	-0.3	3.4	55.1	1.9	3.7	-4.1
1995	3.6	3.6	46.9	1.7	1.4	53.1	0.7	1.2	2.2
1996	2.3	2.5	46.9	1.2	1.3	53.1	0.7	0.5	1.2
1997	5.7	0.8	46.9	0.4	3.4	53.1	1.8	3.5	-2.6
1998	2.1	2.5	46.9	1.2	2.8	53.1	1.5	-0.6	-0.3
1999	4.5	0.7	46.9	0.3	2.8	53.1	1.5	2.7	-2.1

Table 5. Business sector services industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720362	I 720363	I 720364	I 720365	I 720361
1961	26.6	41.2	25.1	34.9	75.5
1962	27.6	42.6	26.3	36.3	75.2
1963	29.1	43.8	27.2	37.4	77.1
1964	31.3	45.7	28.2	38.9	79.7
1965	33.3	47.8	29.7	40.8	80.9
1966	36.0	50.5	31.3	43.1	83.1
1967	37.5	52.3	33.1	45.0	83.0
1968	39.1	52.5	34.8	45.9	84.9
1969	41.1	54.3	36.3	47.6	85.9
1970	43.6	55.1	37.6	48.6	89.3
1971	45.7	56.2	38.7	49.8	91.6
1972	49.1	58.4	39.9	51.6	95.0
1973	52.6	61.4	41.9	54.2	97.0
1974	55.5	64.4	44.3	57.0	97.3
1975	57.4	65.8	46.8	58.9	97.3
1976	60.5	66.2	49.2	60.1	100.6
1977	62.4	68.3	51.5	62.4	100.1
1978	65.7	71.3	53.6	65.0	101.1
1979	69.4	75.3	56.2	68.5	101.4
1980	72.5	77.6	59.8	71.3	101.6
1981	75.0	81.7	63.9	75.4	99.3
1982	72.8	79.8	67.3	75.6	96.2
1983	74.5	80.4	67.9	76.2	97.7
1984	78.3	83.7	69.5	78.9	99.3
1985	83.3	87.2	72.7	82.3	101.4
1986	87.4	90.6	75.8	85.6	102.2
1987	92.0	94.1	80.3	89.5	103.0
1988	96.6	98.2	85.3	93.9	103.0
1989	99.6	101.2	90.0	97.6	102.1
1990	100.1	102.6	95.2	100.2	99.9
1991	98.2	101.1	98.4	100.2	98.0
1992	100.0	100.0	100.0	100.0	100.0
1993	102.8	102.3	105.4	103.3	99.5
1994	109.1	105.6	110.0	107.0	102.0
1995	113.6	108.2	115.2	110.4	103.1
1996	116.2	111.0	120.5	113.9	102.1
1997	121.9	114.0	124.9	117.4	104.0
1998	127.0	117.6	130.5	121.6	104.6
1999	133.3	122.2	136.4	126.6	105.5

Table 6. Breakdown of annual growth in real value added, business sector services industries									
Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ %	Δ %	%	Δ %	Δ %	Δ %
				(2) x (3)			(5) x (6)	(1) - (4) - (7)	(2) - (5)
1962	3.5	4.6	35.8	1.7	3.5	64.2	2.2	-0.4	1.2
1963	5.5	3.4	36.1	1.2	2.7	63.9	1.7	2.5	0.6
1964	7.5	3.9	35.7	1.4	4.4	64.3	2.8	3.3	-0.5
1965	6.4	5.0	35.4	1.8	4.6	64.6	3.0	1.6	0.4
1966	8.2	5.6	35.4	2.0	5.6	64.6	3.6	2.6	0.0
1967	4.3	5.7	35.4	2.0	3.7	64.6	2.4	-0.1	2.0
1968	4.3	5.1	35.0	1.8	0.3	65.0	0.2	2.3	4.8
1969	5.0	4.2	35.1	1.5	3.5	64.9	2.3	1.2	0.7
1970	6.1	3.7	35.8	1.3	1.4	64.2	0.9	3.9	2.3
1971	5.0	2.9	35.1	1.0	2.0	64.9	1.3	2.7	0.9
1972	7.4	3.2	34.1	1.1	4.0	65.9	2.7	3.7	-0.8
1973	7.1	4.9	32.9	1.6	5.0	67.1	3.3	2.1	-0.1
1974	5.5	5.8	32.5	1.9	4.9	67.5	3.3	0.3	0.8
1975	3.3	5.6	32.7	1.8	2.2	67.3	1.5	0.0	3.4
1976	5.4	5.1	32.1	1.6	0.6	67.9	0.4	3.4	4.4
1977	3.2	4.8	32.3	1.5	3.1	67.7	2.1	-0.5	1.7
1978	5.2	4.1	32.9	1.3	4.3	67.1	2.9	1.0	-0.2
1979	5.7	4.8	32.8	1.6	5.7	67.2	3.8	0.3	-0.9
1980	4.3	6.3	32.5	2.1	3.1	67.5	2.1	0.2	3.3
1981	3.5	6.9	32.0	2.2	5.2	68.0	3.5	-2.3	1.7
1982	-2.9	5.3	32.9	1.8	-2.2	67.1	-1.5	-3.2	7.6
1983	2.4	0.8	33.6	0.3	0.7	66.4	0.5	1.6	0.1
1984	5.1	2.4	32.8	0.8	4.0	67.2	2.7	1.6	-1.7
1985	6.5	4.6	33.3	1.5	4.2	66.7	2.8	2.1	0.4
1986	4.8	4.3	33.5	1.4	3.8	66.5	2.6	0.8	0.5
1987	5.3	5.9	32.8	1.9	3.9	67.2	2.6	0.7	2.0
1988	5.0	6.2	32.4	2.0	4.3	67.6	2.9	0.1	1.9
1989	3.1	5.5	31.8	1.8	3.2	68.2	2.1	-0.8	2.4
1990	0.6	5.7	31.1	1.8	1.4	68.9	0.9	-2.2	4.3
1991	-1.9	3.4	30.7	1.0	-1.5	69.3	-1.1	-1.9	4.9
1992	1.8	1.7	30.6	0.5	-1.0	69.4	-0.7	2.0	2.7
1993	2.8	5.4	31.5	1.7	2.3	68.5	1.6	-0.5	3.1
1994	6.1	4.4	32.4	1.4	3.3	67.6	2.2	2.5	1.1
1995	4.2	4.7	32.1	1.5	2.4	67.9	1.6	1.0	2.3
1996	2.3	4.6	32.1	1.5	2.6	67.9	1.8	-1.0	2.0
1997	5.0	3.7	32.1	1.2	2.8	67.9	1.9	1.9	0.9
1998	4.1	4.5	32.1	1.4	3.1	67.9	2.1	0.6	1.4
1999	4.9	4.6	32.1	1.5	3.9	67.9	2.7	0.8	0.6

Table 7. Business sector excluding agriculture – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720340	I 720341	I 720342	I 720343	I 720339
1961	31.8	55.7	28.4	43.5	72.2
1962	33.7	57.9	29.1	45.0	74.1
1963	35.5	59.2	29.9	46.1	76.3
1964	38.4	61.7	30.9	47.9	79.7
1965	41.3	64.9	32.7	50.5	81.2
1966	44.1	68.6	35.0	53.7	81.6
1967	45.5	69.5	37.9	55.6	81.3
1968	48.0	69.3	40.1	56.7	84.2
1969	50.3	70.7	41.6	58.2	86.1
1970	51.7	70.4	43.2	58.8	87.6
1971	54.2	71.5	44.9	60.2	89.7
1972	58.0	73.6	46.3	62.0	93.3
1973	62.8	77.5	48.2	65.0	96.5
1974	64.9	80.5	50.5	67.7	95.6
1975	64.4	80.0	52.7	68.5	93.8
1976	68.5	80.7	54.9	69.9	97.8
1977	71.1	81.5	57.3	71.4	99.5
1978	73.8	83.7	59.5	73.7	100.1
1979	77.2	87.7	61.8	77.0	100.3
1980	78.9	89.3	65.6	79.6	99.0
1981	80.7	91.9	71.3	83.7	96.2
1982	77.1	86.7	76.7	83.1	92.6
1983	79.6	86.2	78.6	83.7	95.1
1984	84.9	89.0	79.8	85.8	98.9
1985	89.8	92.3	81.5	88.5	101.7
1986	92.0	95.3	83.8	91.2	101.0
1987	96.5	99.5	86.3	94.7	102.1
1988	101.5	104.6	89.2	98.9	102.9
1989	103.7	107.2	93.1	102.0	101.8
1990	102.8	106.4	97.0	103.0	99.8
1991	99.3	102.1	99.1	101.0	98.3
1992	100.0	100.0	100.0	100.0	100.0
1993	102.8	101.2	101.8	101.4	101.4
1994	108.9	104.6	103.6	104.2	104.6
1995	113.1	106.8	107.9	107.3	105.6
1996	115.6	109.0	111.8	110.1	105.1
1997	121.8	112.3	113.9	112.9	108.1
1998	125.8	115.7	117.9	116.6	108.1
1999	131.7	120.0	121.4	120.6	109.5

Table 8. Breakdown of annual growth in real value added, business sector excluding agriculture

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri-bution	(5) Labour input	(6) Value labour share	(7) Labour contri-bution	(8) Multifactor produc-tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ %	Δ %	%	Δ %	Δ %	Δ %
				(2) x (3)			(5) x (6)	(1) - (4) - (7)	(2) - (5)
1962	6.1	2.7	36.0	1.0	3.9	64.0	2.5	2.7	-1.2
1963	5.4	2.6	36.6	0.9	2.2	63.4	1.4	3.0	0.4
1964	8.3	3.3	36.5	1.2	4.3	63.5	2.7	4.4	-0.9
1965	7.4	5.9	35.7	2.1	5.2	64.3	3.3	1.9	0.7
1966	6.7	7.1	35.0	2.5	5.7	65.0	3.7	0.5	1.3
1967	3.3	8.2	35.1	2.9	1.2	64.9	0.8	-0.4	7.0
1968	5.4	5.7	35.2	2.0	-0.2	64.8	-0.1	3.5	5.9
1969	4.9	3.8	35.0	1.3	2.0	65.0	1.3	2.3	1.8
1970	2.8	4.0	35.0	1.4	-0.5	65.0	-0.3	1.7	4.4
1971	4.8	3.8	34.7	1.3	1.5	65.3	1.0	2.4	2.3
1972	7.0	3.0	35.2	1.1	2.9	64.8	1.9	4.0	0.1
1973	8.3	4.2	35.8	1.5	5.3	64.2	3.4	3.4	-1.1
1974	3.3	4.7	35.7	1.7	3.9	64.3	2.5	-0.9	0.8
1975	-0.7	4.5	35.3	1.6	-0.7	64.7	-0.4	-1.9	5.2
1976	6.3	4.0	35.3	1.4	0.9	64.7	0.6	4.3	3.1
1977	3.9	4.4	36.1	1.6	1.0	63.9	0.7	1.7	3.4
1978	3.7	3.9	37.7	1.5	2.7	62.3	1.7	0.6	1.2
1979	4.7	3.9	38.7	1.5	4.8	61.3	3.0	0.2	-0.9
1980	2.1	6.1	38.1	2.3	1.8	61.9	1.1	-1.3	4.3
1981	2.3	8.8	36.8	3.2	3.0	63.2	1.9	-2.8	5.8
1982	-4.5	7.5	37.9	2.8	-5.7	62.1	-3.5	-3.8	13.2
1983	3.2	2.5	39.9	1.0	-0.5	60.1	-0.3	2.5	3.1
1984	6.6	1.4	40.0	0.6	3.2	60.0	1.9	4.1	-1.8
1985	5.9	2.2	39.0	0.9	3.7	61.0	2.2	2.7	-1.4
1986	2.5	2.8	38.3	1.1	3.2	61.7	2.0	-0.6	-0.4
1987	4.9	2.9	38.2	1.1	4.4	61.8	2.7	1.1	-1.5
1988	5.2	3.4	37.4	1.3	5.1	62.6	3.2	0.7	-1.7
1989	2.1	4.3	36.3	1.6	2.5	63.7	1.6	-1.0	1.8
1990	-0.9	4.2	34.9	1.5	-0.8	65.1	-0.5	-1.8	4.9
1991	-3.4	2.3	33.9	0.8	-4.1	66.1	-2.7	-1.5	6.3
1992	0.7	0.9	34.3	0.3	-2.0	65.7	-1.3	1.7	2.9
1993	2.8	1.8	36.2	0.6	1.2	63.8	0.8	1.4	0.6
1994	5.9	1.8	38.2	0.7	3.4	61.8	2.1	3.1	-1.6
1995	3.9	4.2	38.8	1.6	2.1	61.2	1.3	1.0	2.1
1996	2.2	3.5	38.8	1.4	2.1	61.2	1.3	-0.4	1.5
1997	5.4	1.9	38.8	0.7	3.0	61.2	1.9	2.8	-1.1
1998	3.2	3.5	38.8	1.4	3.0	61.2	1.8	0.0	0.5
1999	4.7	2.9	38.8	1.1	3.8	61.2	2.3	1.3	-0.8

Table 9. Manufacturing industries – Fisher chain indices of multifactor productivity based on real value added and related data (1992=100)

Year	Real value added	Labour input	Capital input	Combined inputs	Multifactor productivity
CANSIM	I 720373	I 720374	I 720375	I 720376	I 720372
1961	35.8	86.0	38.0	66.7	53.5
1962	40.0	89.2	37.7	68.2	58.5
1963	42.8	91.7	38.3	69.8	61.2
1964	46.9	96.5	39.3	72.8	64.4
1965	51.3	101.5	42.0	77.0	66.8
1966	54.7	106.7	46.0	82.1	66.8
1967	55.8	107.9	51.5	85.7	65.1
1968	59.1	108.1	54.3	87.3	67.8
1969	63.1	109.7	55.3	88.7	71.3
1970	60.7	107.3	57.4	88.3	68.9
1971	64.7	107.4	60.3	89.6	72.4
1972	69.8	110.6	60.5	91.6	76.4
1973	76.3	114.9	62.8	95.1	80.7
1974	77.9	115.8	65.5	96.9	80.8
1975	71.8	111.0	68.3	95.3	75.7
1976	78.1	111.2	69.6	96.0	81.7
1977	81.5	109.8	69.4	95.1	86.1
1978	86.7	113.9	69.6	97.6	89.3
1979	88.5	117.3	69.9	99.7	89.2
1980	86.2	115.8	71.8	99.7	86.9
1981	88.3	114.4	77.8	101.1	87.4
1982	78.9	103.2	83.5	96.1	82.4
1983	83.0	101.0	84.1	94.9	87.8
1984	93.4	103.8	82.0	95.8	97.8
1985	98.3	106.6	80.7	96.9	101.9
1986	99.4	109.7	81.8	99.2	100.6
1987	103.9	113.4	84.4	102.4	101.8
1988	110.2	119.8	87.9	107.6	102.8
1989	112.7	118.8	92.4	109.1	103.7
1990	108.8	112.6	97.7	107.4	101.3
1991	99.1	103.4	99.8	102.2	97.0
1992	100.0	100.0	100.0	100.0	100.0
1993	104.6	99.9	97.1	98.8	105.7
1994	113.3	102.3	94.2	99.0	113.9
1995	118.9	105.7	97.5	102.3	115.7
1996	120.5	108.0	99.9	104.7	114.7
1997	128.9	112.0	101.7	107.7	119.3
1998	133.8	116.5	104.1	111.2	120.0
1999	142.2	120.8	105.5	114.2	124.3

Table 10. Breakdown of annual growth in real value added, manufacturing industries

Year	(1) Real value added	(2) Capital input	(3) Value capital share	(4) Capital contri- bution	(5) Labour input	(6) Value labour share	(7) Labour contri- bution	(8) Multifactor produc- tivity	(9) Capital/ labour ratio
	Δ %	Δ %	%	Δ %	Δ %	%	Δ %	Δ %	Δ %
				(2) x (3)			(5) x (6)	(1) - (4) - (7)	(2) - (5)
1962	11.8	-0.6	33.7	-0.2	3.8	66.3	2.5	9.5	-4.3
1963	6.9	1.4	34.5	0.5	2.8	65.5	1.8	4.6	-1.5
1964	9.6	2.7	34.8	0.9	5.2	65.2	3.4	5.2	-2.5
1965	9.5	6.9	33.3	2.3	5.2	66.7	3.5	3.8	1.7
1966	6.6	9.6	31.2	3.0	5.1	68.8	3.5	0.1	4.5
1967	2.0	11.9	31.0	3.7	1.0	69.0	0.7	-2.4	10.8
1968	5.9	5.4	31.7	1.7	0.2	68.3	0.1	4.0	5.2
1969	6.8	1.9	29.8	0.6	1.5	70.2	1.1	5.2	0.4
1970	-3.7	3.8	28.8	1.1	-2.2	71.2	-1.6	-3.3	6.0
1971	6.5	5.0	30.2	1.5	0.0	69.8	0.0	5.0	4.9
1972	7.8	0.4	31.9	0.1	3.0	68.1	2.0	5.6	-2.6
1973	9.4	3.9	33.4	1.3	3.9	66.6	2.6	5.6	0.0
1974	2.0	4.2	32.2	1.3	0.8	67.8	0.5	0.2	3.4
1975	-7.8	4.3	29.9	1.3	-4.2	70.1	-2.9	-6.1	8.5
1976	8.7	1.9	29.5	0.6	0.2	70.5	0.2	8.0	1.7
1977	4.4	-0.2	30.5	-0.1	-1.3	69.5	-0.9	5.3	1.0
1978	6.3	0.2	32.1	0.1	3.7	67.9	2.5	3.8	-3.5
1979	2.1	0.4	32.4	0.1	2.9	67.6	2.0	-0.1	-2.5
1980	-2.5	2.8	31.2	0.9	-1.2	68.8	-0.8	-2.6	4.0
1981	2.4	8.3	28.2	2.3	-1.2	71.8	-0.9	0.9	9.5
1982	-10.7	7.3	27.9	2.0	-9.8	72.1	-7.1	-5.7	17.1
1983	5.2	0.7	32.6	0.2	-2.1	67.4	-1.4	6.4	2.8
1984	12.5	-2.5	35.3	-0.9	2.8	64.7	1.8	11.6	-5.3
1985	5.3	-1.6	36.1	-0.6	2.6	63.9	1.7	4.2	-4.2
1986	1.1	1.4	37.5	0.5	3.0	62.5	1.8	-1.3	-1.6
1987	4.5	3.2	39.1	1.2	3.4	60.9	2.1	1.2	-0.2
1988	6.1	4.1	38.9	1.6	5.6	61.1	3.4	1.0	-1.5
1989	2.3	5.1	36.9	1.9	-0.8	63.1	-0.5	0.9	5.9
1990	-3.5	5.7	34.1	2.0	-5.3	65.9	-3.5	-2.0	11.0
1991	-8.9	2.1	31.8	0.7	-8.1	68.2	-5.5	-4.0	10.2
1992	0.9	0.2	32.8	0.1	-3.3	67.2	-2.2	3.1	3.6
1993	4.6	-2.9	37.3	-1.1	-0.1	62.7	-0.1	5.8	-2.7
1994	8.3	-3.0	42.2	-1.3	2.5	57.8	1.4	8.1	-5.5
1995	4.9	3.4	44.4	1.5	3.3	55.6	1.8	1.6	0.1
1996	1.4	2.5	44.4	1.1	2.1	55.6	1.2	-0.9	0.4
1997	6.9	1.8	44.4	0.8	3.7	55.6	2.1	4.1	-1.9
1998	3.9	2.3	44.4	1.0	4.1	55.6	2.3	0.6	-1.7
1999	6.2	1.3	44.4	0.6	3.7	55.6	2.0	3.6	-2.3

Glossary

This glossary provides basic definitions of the terms used in measuring productivity. These terms are essential for a clear understanding of some parts of this publication. Further explanations of many of these terms can be found in the text.

Annual average number of hours worked in all jobs. The annual average of hours worked for jobs in all categories.

Business capital investment. Expenditure on assets having a productive life of more than one year (e.g., machinery and equipment). More precisely, it is an expenditure designed to maintain or improve productive capacity. Business capital investment should not be confused with intermediate inputs, which are consumed or transformed during a relatively short production cycle.

Business sector. Productivity measures exclude all non-commercial activities as well as the rental value of owner-occupied dwellings. Corresponding exclusions are also made to compensation and hours worked. In 1992, business sector GDP accounted for about 71% of the Canadian total. The business sector is further divided into the goods sector and the services sector.

Business sector goods industries. Consists of agriculture, fishing, forestry, mining activities, manufacturing, construction and public utilities.

Business sector services industries. Consists of transportation and storage, communications, wholesale and retail trade, finance, insurance and real estate, and the group formed by community, business and personal services.

Chain indices. Indices calculated for consecutive periods to determine price or volume changes from one period to another. Price and volume variations between successive periods are calculated by combining their short-term movement, i.e., by linking the indices for consecutive periods so as to form chain indices.

Choice of the productivity measures. In calculating productivity, a variety of measures of production (and thus factors of production) can be used: value added, gross output and gross output less intra-industry sales. The choice of a measure of productivity will naturally depend on the user's analytical needs. For example, a measure based on value added is interesting because it not only allows international comparisons, but also eliminates double counting when measuring industrial activity.

Combined inputs. A weighted sum of factors of production, particularly labour and capital. The weighting used to combine labour, capital and sometimes other factors (such as energy, raw materials and services) corresponds to the cost share for each factor with respect to total revenue for the sector.

Factors of production. The economic resources used in a firm's production process. A distinction is usually drawn between two primary factors (labour and capital) and intermediate inputs (energy and raw materials). The term 'inputs' is often used to refer to the factors of production.

Fisher chain index. The geometric mean of the Laspeyres and Paasche chain indices. The Fisher chain index treats two compared periods symmetrically. The real GDP indices to determine variations in quantity for the measurement of productivity are based on Fisher chain indices. These offer the advantage of reducing the variation in the values recorded by the various fixed-base indices.

Fixed capital stock. The stock of machinery, equipment, structures (buildings and engineering construction) and tenant-occupied dwellings.

Full-time equivalent employment (FTE). The number of FTEs is the ratio of the number of hours worked in all jobs to the average number of hours worked per year in full-time jobs. This variable is particularly useful in international comparisons with countries that do not have a statistical device to estimate hours worked in all jobs.

GDP at basic prices. The GDP at factor costs *plus* production taxes *less* subsidies.

GDP at factor costs. The measure of GDP corresponding to the value of combined inputs in labour and capital that must be paid by the producer for use of these factors of production. This measure excludes indirect taxes and subsidies.

Gross domestic product (GDP). The total value of goods and services produced within a country's borders, over a given period, regardless of the nationality of the factors of production.

Hours worked in all jobs. The number of hours worked in all jobs is the annual average for all jobs times the annual average hours worked in all jobs. Hours worked is the total number of hours that a person spends working, whether paid or not. In general, this includes regular and overtime hours, breaks, travel time, training in the workplace and time lost in brief work stoppages where workers remain at their posts. It does not include time lost to strikes, lockouts, annual vacation, public holidays, sick leave, maternity leave or leave for personal needs.

Hours worked in all paid jobs. The average number of paid workers during the year multiplied by the annual average number of hours worked in paid jobs.

Industry activity sector. A group of production units all having the same main activity.

Job-to-population ratio. The ratio of the total number of jobs to overall population.

Labour productivity (GDP per hour worked). The ratio of output to hours worked. Economic performance as measured by labour productivity must be interpreted carefully, as these estimates reflect growth in productivity efficiency and changes in other factors of production (such as capital).

Multifactor productivity. A measure of productivity growth, taking into account many of the resources used in the activity of production. Multifactor productivity growth is estimated residually as the difference between the growth rate of output and the growth rate of combined inputs.

Output. The final product of the activity of production obtained from the combination of resources such as labour, capital, materials, services and energy.

Paid jobs. Jobs held by workers whose base pay is calculated at an hourly rate, or on the basis of a fixed amount for a period of at least a week, or in the form of sales commission, piece rates, mileage allowances and so on.

Productivity index. The ratio of the output index to the combined inputs index; the output and the combined inputs are evaluated at constant prices. Expressing productivity levels using indices facilitates comparison and analysis with respect to a base year.

Real GDP per capita. Often used as an indicator of the evolution of a population's standard of living, it is calculated as the real value of production of goods and services divided by total population.

Real GDP per job. An alternate measure of labour productivity. This is calculated by dividing GDP measured in real terms by the total number of jobs. Since this basic definition of labour productivity does not take into consideration time worked, which varies over time and from worker to worker, it is less accurate than the measure of GDP per hour worked. However, this measure can be useful for comparisons with real GDP per capita and is sometimes used to complement productivity analysis.

Total compensation per hour worked or **hourly compensation.** The ratio of the total compensation for all jobs to the number of hours worked.

Total compensation per job. The ratio of the total compensation for all jobs to the total number of jobs.

Total labour compensation. All payments in cash or in kind made by domestic producers to workers for services rendered—in other words, total payroll. It includes the salaries and supplementary labour income of paid workers, plus an imputed labour income for self-employed workers.

Total number of jobs. An estimate that covers four main categories: paid jobs, work for unincorporated businesses, self-employment, and unpaid family jobs. The last category is found mainly in sectors where family firms are important (agriculture and retail trade in particular). Until recently, self-employment and work for an unincorporated business were grouped together as self-employment.

Unit labour cost. The labour cost per unit of output. It equals labour compensation divided by real GDP. It is also equal to the ratio of labour compensation per hour worked to labour productivity. Unit labour cost increases when labour compensation per hour worked increases more rapidly than labour productivity. It is widely used to measure inflation pressures arising from wage growth.

Value added. A measure of production in the same way as is gross output. However, it has the advantage of eliminating double counting. An industry's value added is equal to its gross output (mainly sales) less its intermediate consumption (energy, raw materials and services). Total value added, over all industries, is equal to the GDP at current price for all industries. In order to compare production between different years, it is necessary to eliminate the effect of price change. Therefore, the change in produced quantities only is estimated from the value added in real terms, that is, the value added of a certain period measured in prices of the other period, usually a previous year. This year called the base year (e.g., 1992), is written as '1992=100'. The double-deflation procedure is used to measure real value added: real intermediate inputs are subtracted from real gross output.