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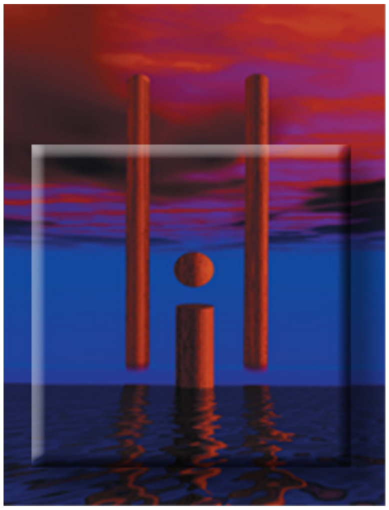

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Productivity Growth in Canada - 2002

John R. Baldwin and Tarek M. Harchaoui
Editors

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A chapter that describes the methodology that is used to estimate the labour services for the calculation of multifactor productivity growth. The methodology recognizes that heterogeneity in the labour force exists just as it does in asset types and develops an index of hours-worked that takes this into account. For this purpose, a weighted average of the growth rates of different types of labour is calculated by weighting individual growth rates by relative wage rates. Average wage rates were developed back to 1961 for strata defined by various characteristics—age, education, and class of worker (employed and self-employed).

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> This chapter outlines the methodology that is used to estimate changes in the amount of capital services used in the production process. The method estimates the user costs of capital for different assets. It then employs these user costs to weight the growth in capital stock of the various assets to produce an estimate of the growth in capital services. The methodology underlying the concept of constructing estimates of capital services recognizes that tangible assets, purchased for the same number of dollars, have different service lives, depreciation rates, tax treatments, and ultimately therefore user costs that are reflected in different marginal products. The methodology makes use of new estimates of depreciation based on age-price profiles of individual assets that are described in Chapter 2. It also provides estimates of capital services under alternate assumptions about the components that enter the formula for the user cost of capital. As a by-product, the chapter ascertains the implications of these new estimates of capital services on a comparison of Canada-U.S. productivity performance.

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Preface

Statistics Canada has recently reengineered its multifactor (called by some the total factor) productivity measure making changes to the series. In this issue of *Productivity Growth in Canada*, we describe in detail these changes.

Multifactor productivity (MFP) growth is measured as the difference in the rate of growth of outputs minus the rate of growth of inputs. It is positive when the rate of growth of produced output exceeds the rate at which inputs are increased. This index captures a number of factors, such as technological change, the exploitation of scale economies, organizational change and, until the revisions, changes in the 'quality' of inputs.

The quality of inputs has until now been included in the estimate of multifactor productivity because the procedure that was followed simply summed all units of labour, or all units of capital, in an unweighted average and then calculated the growth rate in this aggregate. No attempt was made to recognize that some units of labour or capital are more productive than others.

With this revision, we reestimate both our measure of the growth in labour and the growth in capital recognizing that the units are heterogeneous—that each unit has a different marginal productivity. This procedure is in keeping with the spirit of the existing method of calculating multifactor productivity that already weights the growth in each of the labour and capital aggregates by their respective marginal productivities. The new method simply extends the existing methodology to develop the overall measure of labour growth and the overall measure of capital growth to take into account the marginal productivity differences within each category. This is done by calculating the growth rates of subsets of labour and capital and then creating a weighted average of the growth rate of the total category (labour or capital) that uses as weights a proxy for the relative productivity of each type of labour or each type of asset.

This extension is in keeping with best international practice and with the recommendations of the latest OECD productivity manual. But it adds an additional complexity to the estimation process . In creating the new MFP measure, various decisions had to be made. This monograph outlines the nature of the changes made. It also makes use of the measures to examine specific issues.

The first chapter provides a broad overview of how the new measures can be used to analyze Canada/U.S differences in productivity. The multifactor productivity framework has frequently been used to decompose output growth into different components—the portion of growth that is derived from higher employment, more capital, and the residual measure of multifactor productivity—and to compare them across countries. The new estimates of multifactor productivity growth allow new components to be created and used for comparisons. For example, the new estimate of the growth in capital can be broken down into more detailed asset types. In this chapter, we break out the information and communications asset component and ask whether it contributes more to growth in Canada than the United States.

Chapters 2 and 4 focus on how the measure of the growth in capital was created. We weight the various asset types by their relative marginal productivity, which we estimate from the capital services derived therefrom. Capital services are just the stock of capital multiplied by the user cost of capital. To measure the user cost of capital, we require, amongst other things, an estimate of the depreciation rate. The second chapter outlines how the depreciation rate was estimated. A special micro dataset on used asset prices that was derived from a Statistics Canada survey was used for this purpose. This chapter examines the procedures that were used and the results obtained.

The fourth chapter discusses the method that was used to develop a measure of the growth in capital. It first describes the assumptions of capital theory upon which we rely. It then outlines the extensions to our asset list that are made. In particular, land and inventories are now included among the assets considered. It then describes the data on depreciation, on rates of return, on tax rates, and capital gains that were required to estimate the user cost of capital of each asset. In several instances, choices among alternatives had to be made. For example, the academic literature alternately chooses the rate of return as the long-term bond rate or the realized rate of return to capital in the industry. The fourth chapter describes the alternatives, the differences in the capital stock growth that results from the use of these alternate methods, and the reasons for the method ultimately chosen.

The third chapter develops the new method that is used to estimate the rate of growth in labour inputs. The rates of growth of different labour types are weighted by their relative marginal productivity—as estimated by their relative wage rates. The chapter describes the assumptions that are required to substantiate this methodology, the labour types that are chosen, and the data used to estimate relative wage rates. As with the capital estimates, alternate assumptions and data sources are available. Each is discussed in turn and the differences from using alternatives are outlined.

The fifth chapter does not fall within the scope of the others that focus on the multifactor productivity program. But it is important because it describes one of the key outputs of the labour productivity program—the measure of unit labour costs. The measure of unit labour costs is produced in association with the estimates of labour productivity (output per worker) and is used by many analysts to forecast wage pressures or to examine the 'competitiveness' of a sector. In essence, this measure compares the rate of growth of unit wages with the growth in labour productivity. The fifth chapter describes what the measure does and how it is derived. It compares unit labour costs to a broader measure that considers not just labour costs but also other variable inputs. It then describes the relationship between changes in Canada's unit labour costs relative to that of the United States and Canada's export growth, showing the close connection of this measure to Canada's success in export markets.

John R. Baldwin
Tarek M. Harchaoui
Editors

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A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies

Philip Armstrong, Tarek M. Harchaoui, Chris Jackson and Faouzi Tarkhani

1.1 Introduction

Information and communication technology (ICT) equipment appears to be almost everywhere—on the desks of executives, on the factory floor, in the classroom, at home, and, these days, even in people's pockets. By all accounts, ICT appears to be rapidly changing the way many enterprises conduct business and communicate. The proliferation of ICT has made the world seem much smaller, as computer-related innovations, such as the Internet, let individuals on opposite sides of the world interact in ways that were unimagined 20 years ago.

The explosion of ICT spending over the last few decades has sparked renewed interest in the role of investment and capital accumulation as sources of economic growth. While productivity growth, capital accumulation, and the impact of technology were topics once reserved for academic debates, the recent success of the U.S. economy has moved them into the popular domain (see Jorgenson and Stiroh, 2000; see also Khan and Santos, 2002 for a Canada-U.S. comparison).

Using revised data on output and capital input, this paper sheds some new light on the changing composition of investment and the growth of capital services in Canada during the 1990s and makes comparisons to the 1980s. In particular, well-tested and familiar methods are employed to estimate annual indices of capital services for the Canadian business sector from 1981 to 2000 and a decomposition into quantity and quality components for broad asset classes, including ICT equipment, is introduced. While much of the recent Canadian economic literature has documented the growing importance of computers, the extent to which ICT and other types of capital have contributed to economic growth in Canada are examined and compared. As a by-product, the underpinnings of the productivity performance of the Canadian and U.S. business sectors over the last two decades are examined using comparable methodologies.

Our approach distinguishes between *capital quantity* growth due to investment, and compositional change of asset types (sometimes referred to as *capital quality* growth) due to substitution between different types of capital assets. Much of the recent investment boom reflects substitution towards high-tech assets as their relative price steadily fell. Quantity and quality decompositions for broad asset classes, such as ICT, other machinery and equipment (made of low-tech equipment), and various types of structures are also introduced.

Our primary conclusion is that the Canadian business sector has experienced a steady and pervasive increase in the growth rate of capital services during the second half of the 1990s. The growth of capital services—including fixed reproducible capital, land, and inventories—has increased from an average annual growth rate of 3.5% for 1981-1988 to 4.2% for 1995-2000.

When sources of Canadian economic growth in output from 1995 to 2000 are examined, the data show that capital and labour continue to make important contributions to overall growth. The increase in the growth of investment, from 1.7% per year over 1981-1988 to 11.9% over 1995-2000, has led to an increase in the contribution of capital services from 1.4% to 1.7% per year between these two periods. Due to strong investment and an increasing input share, high-tech equipment is the only class of fixed reproducible assets that is making a significantly larger contribution to output growth in the second half of the 1990s relative to the 1980s.

During the post-1995 period, the growth contribution of labour input has advanced primarily as a result of the increase in hours worked. The contribution of labour quality declined, a reflection of a falling unemployment rate as more workers with relatively lower marginal products were drawn into the workforce during this period.

The third primary source of growth, multifactor productivity or the famous Solow residual, grew at 0.2% per year on average during the last two decades in Canada, compared to 0.9% per year for the U.S. The acceleration of multifactor productivity in Canada from -0.3% per year over 1988-1995 to 1.0% per year during the post-1995 period (0.5% to 1.3% in the U.S.) suggests considerable improvements in technology and increases in the efficiency of production. While the resurgence in multifactor productivity growth in the post-1995 period has yet to surpass the pre-1973 performance, more rapid multifactor productivity growth is critical for sustained growth at higher rates.

During the post-1995 period, multifactor productivity contributed 21% of the output growth in Canada (27% for the U.S.), up from 6.1% in the 1981-1988 period (26% for the U.S.). Although the recent resurgence in multifactor productivity in both countries does not surpass the pre-1973 performance, it is certainly one of the most important stylized facts of the end of the twentieth century.

The remainder of the paper is organized as follows: Section 1.2 discusses the data sources and the historical trends of investment and capital formation. Section 1.3 analyzes the impacts of these trends on labour productivity and multifactor productivity performance. Section 1.4 concludes the paper.

1.2 Capital and the Aggregate Production Function

1.2.1 General Description of the Data

This paper is based on methodologies recently implemented by the productivity program at Statistics Canada that constructs new Fisher indices of output and inputs for the Canadian business sector that are then used to construct multifactor productivity estimates.

The Fisher output indices use the expenditure based GDP estimates released in the Income and Expenditure Accounts on May 31, 2001, but exclude out-of-scope components such as the government sector, non-profit institutions and the rental on owner-occupied dwellings. Corresponding adjustments are also made to capital stock and hours worked. The GDP estimates incorporate the capitalization of software expenditures making the Canada-U.S. estimates of economic growth comparable for the first time since October 1999 when the U.S. Bureau of Economic Analysis introduced this change during a comprehensive historical revision to their National Income and Product Accounts.

Statistics Canada's new methodology for estimating the growth of capital services that is appropriate for an aggregate production function analysis is outlined in Chapter 4. The estimation procedure begins with estimates of real investment flows by detailed asset class, then calculates capital stock for each asset class by industry using the perpetual inventory technique. It then estimates the user cost of capital for each industry using Input-Output Tables to derive rates of return at the industry level, micro-economic price data on over 30,000 sales of used assets to obtain depreciation rates (see Chapter 2) and detailed information on tax rates. The growth rates of the stock of capital by asset type of individual industries are then aggregated using the user cost of capital to derive an estimate of the growth in the flow of capital services by industry.

For the analysis in this paper, the wide number of assets used in the productivity program (28 classes) are grouped into three distinct classes. Table 1.1 shows the concordance that produces three broad asset classes—ICT, other machinery and equipment, and structures (which includes inventories and land).[1] This taxonomy not only distinguishes long-lived structures from short-lived equipment, but also information and communications technologies (ICT) from other machinery and equipment.

This paper also uses estimates of labour growth that take into account differences in marginal productivity across labour types (see Chapter 3). Contrary to the method that just sums all hours-worked across all workers, the method that considers differences across labour types sums the growth in hours-worked of different classes of labour weighted by their relative wage rates or their share of labour compensation. Much like the estimates of capital input that capture substitution across asset classes, the approach developed by Jorgenson, Gallop and Fraumeni (1987) for aggregate labour input allows for substitution between various types of labour, e.g., workers cross-classified by education, experience, and other characteristics. This approach allows for a breakdown of the growth of labour input into growth of labour hours and a labour composition or labour quality effect that is similar to the breakdown in capital growth between the straight sum of all capital and changes in its composition.

1.2.2 Capital Stock Estimates in Current Prices

Table 1.2 contains a breakdown of assets into major groupings and the 1981 and 2000 value of capital stock by asset class. The perpetual inventory calculations result in a net stock of fixed reproducible assets of $929 billion in current dollars in 2000, up from $290 billion in 1981. Adding in the estimated value of land and inventories yields a total capital stock of $1.3 trillion in 2000.

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[1] The definition of information and communications technologies (ICT) assets, which includes computer hardware, software and telecommunication equipment, is chosen to permit comparisons with the U.S. (see U.S. Bureau of Labor Statistics 2000). There are currently efforts underway within the OECD to define a broader set of ICT commodities which include not only the investment assets used in our definition but also intermediate goods and services, and final demand categories.

Table 1.1 Classification of Capital by Asset Class

Information and Communication Technology
Computers and Office Equipment
Communication Equipment
Software – Own Account
Software – Pre-Packaged
Software – Custom Design

Other Machinery and Equipment
Office Furniture, Furnishing
Household and Services Machinery and Equipment
Electrical Industrial Machinery and Equipment
Non-Electrical Industrial Machinery and Equipment
Industrial Containers
Conveyors and Industrial Trucks
Automobiles and Buses
Trucks (excluding Industrial Trucks) and Trailers
Locomotives, Ships and Boats and Major Replacement Parts
Aircraft, Aircraft Engines and Other Major Replacement Parts
Other Equipment

Structures
Non-Residential Building Construction
Road, Highway and Airport Runway Construction
Gas and Oil Facility Construction
Electric Power, Dams and Irrigation Construction
Railway and Telecommunications Construction
Other Engineering Construction
Cottages
Mobile Homes
Multiple Dwellings
Single Dwellings
Inventories
Land

Table 1.2 Estimates of Net Capital Stock by Asset Class: Canadian Business Sector

	1981 Capital Stock			2000 Capital Stock		
	Value $	Fixed Capital Share (%)	Total Capital Share (%)	Value $	Fixed Capital Share (%)	Total Capital Share (%)
	(millions of current dollars)					
Total Capital Stock	492,588		100.0	1,278,237		100.0
Fixed Reproducible Capital	290,465	100.0		929,409	100.0	
Information, Communication and Technology	11,363	3.9	2.3	59,900	6.4	4.7
Computers and Software	4,444	1.5	0.9	37,493	4.0	2.9
Communication	6,920	2.4	1.4	22,407	2.4	1.8
Other Machinery and Equipment	80,948	27.9	16.4	238,505	25.7	18.7
Structures	198,153	68.2	40.2	631,008	67.9	49.4
Inventories and Land	202,123		41.0	348,828		27.3
Structures, Land and Inventories	400,276		81.3	979,832		76.7

The investment in ICT in constant prices (see Table 1.3) has grown at an average annual rate of 16.2% during the 1981-2000 period, much faster than the other two classes of assets. Despite this rapid growth, however, ICT equipment remains a small share of the business sector's aggregate capital. In 2000, ICT capital stock in nominal terms accounted for 6.4% of fixed reproducible capital, which includes equipment and structures, up from 3.9% in 1981 (see Table 1.2). In our broader definition of capital stock that includes residential assets, land and inventories, ICT assets account for an even smaller share (4.7% in 2000 compared to 2.3% in 1981).

1.2.3 Growth of Investment, Capital Stock, and Capital Services

The growth in Canada's use of capital can be examined using three related data series—an index of the growth in investment, an index of the growth in capital stock (a straight sum of the different assets) and an index of the growth in capital services—from 1981 to 2000. Furthermore, each of these can be decomposed into three components: that arising from investments in ICT, other machinery and equipment, and structures (which include land and inventories).[2]

To better understand aggregate trends, average annual growth rates (in terms of both quantities and prices) are presented in Table 1.3 for each series for the major asset classes and for the entire period 1981-2000, and for three sub-periods: 1981-1988, 1988-1995, and 1995-2000. Growth rates for business sector GDP for the same periods are also reported.

The dominant feature of these estimates is the significant drop of output growth during the early 1990s recession. After growing around 3.3% per year during 1981-1988, output growth fell to 1.6% per year for 1988-1995 and recovered remarkably during the second half of the 1990's to reach 4.9% per year on average. Investment, capital stock and capital services all show similar growth patterns.

1.2.4 Investment

While investment showed a similar growth pattern to growth in output, growth in investment showed more sensitivity to the business cycle. It slowed dramatically from 1.7% per year during 1981-1988 to -0.2% for 1988-1995. However, it surged to 11.9% for 1995-2000, helping to boost GDP growth during this period.

There is substantial variation in the growth rates across asset classes and an accelerating trend toward equipment investment, particularly ICT. Real ICT investment growth was high and rising throughout the last two decades. Despite the GDP slowdown, it was 13.2% per year even during the slow growth in the early 1990s. On the other hand, real investment in non-residential structures and other machinery and equipment dropped to -1.9% and -2.1% per year, respectively, during the period 1988-1995. In recent years, investment in all of the asset classes grew at a much higher pace than during the 1981-1988 period.

The more rapid growth of ICT can be understood by examining the behaviour of relative prices. The rate of inflation of the GDP deflator declined from 4.5% per year (1981-1988) to 2.4% per year (1988-1995) and then to 1.4% per year (1995-2000). The quality-adjusted price of ICT investment goods fell during the same three post-1981 periods (-14.5% to -8.0% to -3.2% per year). Relative to the GDP deflator, ICT prices

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[2] See the appendix of Chapter 4 for the differences between these various concepts.

Table 1.3 Average Annual Growth Rates of Investment, Capital Stock, Capital Services and Output: Canadian Business Sector (%)

	Investment Index		Capital Stock Index		Capital Services Index		GDP	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
1981-2000								
GDP	–	–	–	–	–	–	2.9	3.0
All Assets	1.0	3.6	1.0	2.0	4.2	3.4	–	–
ICT	-9.3	16.2	-9.3	12.7	-1.5	21.0	–	–
Other Machinery and Equipment	2.5	2.0	2.5	2.1	5.6	3.4	–	–
Structures	1.5	0.8	1.5	1.7	6.8	2.1	–	–
1981-1988								
GDP	–	–	–	–	–	–	4.5	3.3
All Assets	0.5	1.7	0.5	1.8	6.4	3.5	–	–
ICT	-14.5	11.5	-14.5	8.0	-1.4	21.5	–	–
Other Machinery and Equipment	2.9	2.2	2.9	1.7	7.8	3.7	–	–
Structures	1.7	0.4	1.7	1.9	8.5	2.4	–	–
1988-1995								
GDP	–	–	–	–	–	–	2.4	1.5
All Assets	1.8	-0.2	1.8	1.3	3.7	2.6	–	–
ICT	-8.0	13.2	-8.0	11.5	-2.8	17.5	–	–
Other Machinery and Equipment	2.4	-2.1	2.4	1.2	2.2	1.6	–	–
Structures	2.0	-1.9	2.0	1.3	7.2	1.6	–	–
1995-2000								
GDP	–	–	–	–	–	–	1.4	4.9
All Assets	0.7	11.9	0.7	3.5	1.7	4.2	–	–
ICT	-3.2	27.6	-3.2	21.3	0.3	25.1	–	–
Other Machinery and Equipment	2.0	7.7	2.0	4.1	7.5	5.5	–	–
Structures	0.3	5.6	0.3	2.1	4.1	2.5	–	–

fell at an average of 12.2% per year over the 1981-2000 period. The other categories of investment experienced price increases, but in general they were still lower than those of the GDP deflator.

These investment patterns directly determine the growth of the capital stock. For example, relatively fast ICT equipment investment leads to faster capital stock growth rates and an increase in the capital stock share of equipment.

The long-lived nature of structures, however, means this occurs slowly. The index of real capital stock of ICT equipment, for example, has grown 12.7% per year over the last two decades, while structures grew only 1.7% per year. The share of ICT equipment in the stock of fixed reproducible capital in current dollar terms has increased from 3.9% in 1981 to 6.4% in 2000. This important increase in the value share is due to the large increase in the quantity of ICT capital that more than offset the fall in the price of such capital.

1.2.5 Capital Formation

The indices of the growth of Canadian capital stock and capital services show that the post-1995 period has been one of relatively rapid growth in capital stock. The rate of growth of capital fell from 1.8% per year from 1981-1988 to 1.3% per year from 1988-1995 and rebounded sharply to 3.5% per year from 1995-2000. At the asset level, however, while ICT equipment maintained a sustained growth across all periods, both machinery and equipment and structures experienced a significant slowdown during the 1988-1995 period, followed by a marked recovery in recent years.

Trends in the growth of the capital stock are major determinants of the growth of capital services. The growth of capital services is, however, higher than the growth of capital stock, reflecting the ongoing substitution of short-lived equipment for long-lived structures. This shift in composition is sometimes referred to as changes in capital quality—in the sense that it results from changes in composition that are associated with changes in marginal productivity. All else being equal, a short-lived asset has a higher depreciation rate, relatively higher service price and, therefore, a higher relative marginal productivity since competitive markets equate user capital cost to marginal productivity. As a consequence, the fast growing short-lived assets receive a higher weight in the capital service aggregation compared to their weight for the capital stock (see Chapter 4). For individual asset classes, the results in Table 1.3 show that capital-service growth always exceeds the growth of the capital stock, which implies asset substitution also occurs within asset classes.

These data document an important recovery in the growth rate of Canadian capital services across all asset classes in the post-1995 period. This reflects in large part the rapid growth of investment in the second half of the 1990s for all asset classes. This is an important development since it is the growth of capital services and not the level of capital or investment growth that ultimately affects economic growth in output.

As a point of comparison, it is useful to compare these results to the measure of capital services reported for 1999 by the U.S. Bureau of Labor Statistics (BLS) (2000). For the private business sector, which most closely matches our estimates, BLS (2000) reports capital services growth of 3.8% for all assets for 1981-1999, slightly above our estimate of 3.3% for the same period. This may reflect structural differences between the two countries.

Table 1.4 Decomposition of the Growth in Capital Services by Asset Class: Canadian Business Sector

	Within Quality Effect	Between Quality Effect	Weighted Capital Accumulation	Capital Services Growth
		(annual average growth rates %)		
		1981-2000		
Fixed Capital	0.9	0.3	2.1	3.4
Information and Communication Technology	0.4	0.3	0.5	1.2
Other Machinery and Equipment	0.3	0.1	0.4	0.8
Structures	0.2	-0.1	1.2	1.4
		1981-1988		
Fixed Capital	1.4	0.1	2.0	3.5
Information and Communication Technology	0.6	0.2	0.2	1.0
Other Machinery and Equipment	0.5	0.1	0.3	0.9
Structures	0.3	-0.1	1.4	1.6
		1988-1995		
Fixed Capital	0.7	0.3	1.7	2.6
Information and Communication Technology	0.4	0.3	0.4	1.1
Other Machinery and Equipment	0.1	0.1	0.3	0.4
Structures	0.2	-0.1	1.0	1.1
		1995-2000		
Fixed Capital	0.7	0.6	2.9	4.2
Information and Communication Technology	0.2	0.6	0.8	1.6
Other Machinery and Equipment	0.3	0.1	0.8	1.2
Structures	0.2	-0.1	1.3	1.4

For both countries, the trends are quite similar during the various sub-periods. BLS (2000) reports a decrease in the growth of capital services from 3.9% for 1981-1988 to 2.8% for 1988-1995 and then a recovery to 5.3% for 1995-1999 (3.5%, 2.6% and 4.2%, respectively, for Canada). However, there are marked cross-country differences in the growth of capital services at the asset level. The U.S. ICT equipment capital services grew 17.5% during the 1995-1999 period, up from the 14.5% and 8.5% posted, respectively, during the 1981-1988 and 1988-1995 periods. This is far below the performance experienced by its Canadian counterpart (25.7%, 21.5% and 17.5%, respectively). Although in the U.S., other machinery and equipment and structures recovered in the 1995-1999 period in comparison with the 1988-1995 period, this performance remains below that posted in the previous decade. In contrast, during the 1995-1999 period, Canadian other machinery and equipment and structures experienced their fastest growth of the last twenty years.

1.2.6 Decomposing the Growth in Capital Services

The previous section showed an increase in the growth of capital services for fixed capital and its asset classes but has neither identified nor quantified the sources of this increase in terms of changes in composition of investment within asset classes and between asset classes. This section does just that. It provides a framework that decomposes the growth in capital services into three major components. In this framework, capital services increase for three reasons—substitution towards short-lived, high marginal product assets within asset classes (within quality effect), substitution between asset classes (between quality effect), and the accumulation of capital stock (capital accumulation effect).

The growth of aggregate capital services (the log represents the growth rate) is decomposable as follows (see Ho, Jorgenson and Stiroh 1999):

$$\ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) = \sum_j \overline{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j (\overline{v}_t^j - \overline{w}_t^j)\ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right) + \sum_j \overline{w}_t^j \ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right). \quad (1)$$

where $\tilde{K}_t$, Δ_t^j, $\overline{K}_t^j$ represent, respectively, aggregate capital services, quality change of the asset class $j = \mathrm{ICT}$, other machinery and structures and the capital stock of the asset class j at period t ; $\overline{v}_t^j$ and $\overline{w}_t^j$ are, respectively, average rental cost share and average value share of capital stock for the asset class j at period t .

Each of these three components has a specific economic interpretation. The first term on the right-hand side will be referred to as the "within quality effect," which measures substitution and capital quality growth within distinct asset classes. The second term represents the "between quality effect," which measures substitution between distinct asset classes. The last term is the "capital accumulation effect," which measures capital stock accumulation.

Table 1.4 presents the contribution to the growth in total fixed capital services from each component for 1981-2000 and sub-periods. The decomposition allows us to identify the sources of increase of capital services growth by comparing each component across asset classes and over time. Table 1.4 should be read in the following manner. Consider the 3.4% per year growth of capital services for the 1981-2000 period (last column, first row). This is made up of a 1.2% contribution from ICT, 0.8% from other machinery and equipment and 1.4% from structures. Looked at from the decomposition outlined in equation 1, this 3.4% comes from 0.9% of a within-class effect (substitution across assets within an asset class), 0.3% from a between-class effect (substitution across asset classes), and 2.1% from a capital-accumulation effect (general growth across all asset classes).

The estimates show that at the aggregate level the capital-accumulation effect is the primary source behind the growth of total capital services for all periods. However, this varies across asset classes: the total quality effect (the sum of the within and between quality effect) constitutes the major source behind the growth of ICT capital services for all periods, while the capital-accumulation effect tends to dominate for other machinery and equipment and structures. Substitution across asset groups within an asset class becomes increasingly important over time, particularly for ICT.

For all periods and all asset classes, the total quality effect is primarily driven by the within quality effect. However, the 0.7 percentage point annual increase of capital services between 1981-1988 and 1995-2000, which is mainly attributable to ICT and other machinery and equipment, is mostly driven by the between-effect and the capital-accumulation effect, which increased by 0.5 and 0.9 percentage points per year, respectively.

1.3 A Decomposition of Growth

1.3.1 Framework

The growth of capital services along with the growth in labour input and multifactor productivity are the three primary determinants of the economic growth in output. The final part of this paper evaluates the relative importance of these sources of Canadian economic growth during the period 1981-2000.

This type of growth accounting exercise has a rich history beginning with the seminal work of Solow (1957), who integrated the aggregate production function with national income data to produce an estimate of productivity growth that captured disembodied technical change. Aggregate output Y_t is considered to be produced from capital services $\tilde{K}_t$ and labour services $\tilde{L}_t$. Representing productivity as a 'Hicks-neutral' augmentation A_t of aggregate input, output can be written as:

$$Y_t = A_t F\left(\tilde{K}_t, \tilde{L}_t\right) \tag{2}$$

Under the assumptions of competitive product and factor markets, and constant returns to scale, growth accounting gives the growth of output as the sum of the share-weighted growth of inputs and growth in multifactor productivity:

$$\Delta \ell n Y_t = \bar{s}_{K,t} \Delta \ell n \tilde{K}_t + \bar{s}_{L,t} \Delta \ell n \tilde{L}_t + \Delta \ell n A_t \tag{3}$$

where $\bar{s}_{K,t}$ and $\bar{s}_{L,t}$ are respectively, capital's and labour average share of nominal value-added, $\bar{s}_{K,t} + \bar{s}_{L,t} = 1$, the augmentation factor A_t captures multifactor productivity and Δ refers to a first difference.

Equation (3) has several attractive features. It facilitates the decomposition of the growth in output into the contributions made by labour and capital inputs on one hand, and a residual that is called multifactor productivity growth, on the other hand. It also allows for the quantification of the contributions of different types of capital, such as ICT, to the growth of output.

In addition, rearranging equation (3) enables us to present results in terms of labour productivity growth

$$\Delta \ell n \left(\frac{Y_t}{H_t}\right) = \bar{s}_{K,t} \Delta \ell n \left(\frac{\tilde{K}_t}{H_t}\right) + \bar{s}_{L,t}\left(\Delta \ell n \tilde{L}_t - \Delta \ell n H_t\right) + \Delta \ell n A_t \tag{4}$$

where $\frac{Y_t}{H_t}$ and $\frac{\tilde{K}_t}{H_t}$ are, respectively, output per hour worked and the ratio of capital services to hours worked. This gives the familiar formula that allocates labour productivity growth among three factors. The first is *capital deepening*, the growth in capital services per hour. Capital deepening (also called *capital intensity*) makes workers more productive by providing more capital for each hour of work and raises the growth of labour productivity in proportion to the share of capital. The second term is the improvement in labour quality, defined as the difference between the weighted growth rates of each category of labour and the growth in the simple sum of hours worked across all worker categories. Reflecting the rising proportion of hours supplied by workers with higher marginal products, labour quality improvement (also called the *labour composition effect*) raises average labour productivity growth in proportion to labour's share. The third term is *multifactor productivity* growth, which increases labour productivity growth on a point-for-point basis. Long-term labour productivity growth arises from three sources: multifactor productivity growth, the contribution of increased capital intensity, and the contribution of shifts in labour composition.

As shown in equation (4), labour productivity (output per hour) can differ from multifactor productivity (output per unit of combined capital and labour inputs) if capital deepening occurs or if labour quality improves.

The remainder of this section provides empirical estimates of the variables in equations (2) through (4). Equations (3) and (4) are then employed to quantify the sources of growth of output and average labour productivity for 1981-2000 and various subperiods.

1.3.2 Empirical Results

This section provides the results associated with equations (3) and (4), which provide two different but related perspectives on the sources of growth: the latter decomposes the sources of labour productivity growth and the former identifies the sources of economic growth of total output. The section commences with an examination of the sources of labour productivity growth.

1.3.3 The Sources of Labour Productivity Growth

The contribution of capital intensity to labour productivity growth equals the growth in the capital-hours ratio multiplied by capital's share of nominal value-added. The contribution of labour composition equals the difference between the growth rates of labour input and of hours worked multiplied by labour's share of nominal value-added. Historically, capital's share has been slightly more than one-third of nominal value-added in the business sector.

Table 1.5 indicates that from 1981 to 2000, labour productivity grew at an annual rate of 1.4% in the business sector. Of the 1.4% growth in labour productivity, 0.2% can be attributed to increases in multifactor productivity, 0.6% to the contribution of capital intensity, and 0.5% to changes in labour composition. Table 1.5 displays a moderate labour productivity increase during the 1980s and early 1990s, and an acceleration of labour productivity growth in the late 1990s. This acceleration reflects the remarkable pick-up in multifactor productivity growth in recent years.

During 1988 to 1995, multifactor productivity decreased -0.3% per year in the business sector. At the same time, the average annual contribution of capital intensity to labour productivity growth increased to 0.9%, and labour composition made a 0.6 percentage point contribution. Labour productivity, therefore, increased 1.2% per year from 1988 to 1995. ICT capital began to play an increasingly important role during this period, contributing 0.4% per year, or more than two-fifths of the contribution of capital deepening to labour productivity growth.

Table 1.5 Annual Average Percentage Point Contribution to Labour Productivity: Canadian Business Sector

	1981-2000	1981-1988	1988-1995	1995-2000
Labour Productivity Growth (annual average growth rate)	1.4	1.3	1.2	1.7
Capital Deepening	0.6	0.6	0.9	0.4
Information and Communication Technology	0.4	0.3	0.4	0.4
Other Machinery and Equipment	0.1	0.1	0.1	0.1
Structures	0.1	0.1	0.3	-0.1
Labour Quality	0.5	0.5	0.6	0.3
Multifactor Productivity (annual average growth rate)	0.2	0.2	-0.3	1.0

Table 1.6 Sources of Economic Growth: Canadian Business Sector

	1981-2000	1981-1988	1988-1995	1995-2000
		(annual average percentage point contribution)		
Output Growth (annual average growth rate)	3.0	3.3	1.5	4.9
Contribution of Capital Services	1.3	1.4	1.0	1.7
Information Communication Technology	0.5	0.4	0.4	0.7
Other Machinery and Equipment	0.3	0.4	0.2	0.5
Structures	0.5	0.6	0.4	0.5
Contribution of Labour Input	1.5	1.7	0.8	2.2
Multifactor Productivity (annual average growth rate)	0.2	0.2	-0.3	1.0
Contribution of Capital Stock	0.9	0.8	0.6	1.4
Contribution of Capital Quality	0.5	0.6	0.4	0.3
Contribution of Labour Hours	1.0	1.2	0.1	1.9
Contribution of Labour Quality	0.5	0.5	0.6	0.3

Table 1.7 The Sources of Economic Growth Canada and U.S., Business Sector

	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
	1981-1999		1981-1988		1988-1995		1995-1999	
				(annual average percentage point contribution)				
Output (annual average growth rate)	2.9	3.6	3.3	3.9	1.5	2.2	4.8	4.9
Contribution of Labour Input	1.4	1.5	1.7	1.6	0.8	0.9	2.1	1.8
Contribution of Capital Services	1.3	1.2	1.4	1.3	1.0	0.8	1.7	1.8
Contribution of ICT	0.5	0.5	0.4	0.4	0.4	0.3	0.7	1.1
Contribution of Other Machinery and Equipment	0.3	0.3	0.4	0.4	0.2	0.2	0.5	0.4
Contribution of Structures	0.5	0.4	0.6	0.4	0.4	0.2	0.6	0.4
Multifactor Productivity (annual average growth rate)	0.2	0.9	0.2	1.0	-0.3	0.5	1.0	1.3

U.S. data are taken from the U.S. Bureau of Labor Statistics (2000).
Numbers may not add due to rounding.

During 1995-2000, labour productivity grew 1.7% per year in the business sector, 0.5 percentage points faster than during the 1988-1995 period. This acceleration is attributed entirely to the remarkable resurgence of multifactor productivity growth, which increased by more than one percentage point. Continuing the trend in substitution of ICT for other forms of capital, ICT capital accounted for the whole contribution of capital deepening to labour productivity growth. Growth in labour quality slowed relative to the growth in hours in the 1995-2000 period.

1.3.4 The Sources of Economic Growth

Using the framework developed above, the capital and labour inputs are combined with output data to estimate the components of equation (3) to quantify the sources of economic growth in output from 1981-2000. In addition to the standard contribution of aggregate capital services, the analysis also examines the contribution of each broad asset class to total growth.

Results are reported in Table 1.6 and should be read in the following manner. In the second column, for the period 1981-1988, output grew at 3.3% per year, of which aggregate capital services contributed 1.4%, labour input 1.7%, and multifactor productivity 0.2%. The 1.4% capital contribution is from the growth rate of capital services multiplied by the $\overline{s}_{K,t}$ share and may also be decomposed into a 0.8% contribution of capital accumulation and 0.6% of quality change. Similarly, the 1.7% labour input contribution can be decomposed into a 1.2% contribution from increased hours worked and a 0.5% contribution from quality change due to substitution toward more highly educated workers.

For 1995-2000, output grew 4.9% per year, capital services contributed 1.7 percentage points, labour input contributed 2.2 percentage points, and multifactor productivity contributed 1.0 percentage points.

As reported above, there has been an increase in the contribution of capital services during 1995-2000 since the growth contribution increased to 1.7% from 1.4% per year over 1981-1988. ICT shows the largest increase in the contribution of capital services between the two periods, nearly doubling from 0.4% to 0.7%. In addition, the most recent estimates show an increase in the growth of multifactor productivity that is above any rate since 1981.

1.3.5 Canada-U.S. Comparison of Multifactor Productivity Growth

An examination of Table 1.7 for both the Canadian and U.S. business sectors over 1981-1999, the most recent period for which U.S. multifactor productivity estimates are available, reveals that Canada's multifactor productivity grew at 0.2% per year on average, compared to 0.9% per year for the U.S. This productivity gap between the two countries is largely attributable to Canada's relatively modest multifactor productivity performance from 1981 to 1995. The lack of multifactor productivity gain in Canada from 1981 to 1995 (0.0% compared with 0.7% in the U.S.) reflects a 2.4% increase in output (3.3% in the U.S.) and a 2.4% increase in combined inputs of capital and labour (2.5% in the U.S.).

In the late 1990s, output grew at an average annual rate of 4.8% in Canada (4.9% for the U.S.), a 3.2 percentage point increase relative to the early 1990s (2.7 percentage points for the U.S.). Multifactor productivity growth makes an important recovery to 1.0% in

Canada (1.3% for the U.S. as well), while capital services' contribution to growth recovered to 1.7% in Canada (1.8% in the U.S.), and labour's contribution rebounded to 2.1% points (1.8% for the U.S.).

Multifactor productivity growth is the source of 21% of output growth in Canada (27% in the U.S.), up from 6.1% in the 1981-1988 period (26% for the U.S.). The acceleration in multifactor productivity growth in Canada and the U.S. is perhaps the most remarkable feature of the data. Its acceleration in Canada from -0.3% per year to 1.0% per year (0.5% to 1.3% in the U.S.) between 1988-1995 and 1995-1999 suggests considerable improvements in technology and increases in the efficiency of production. While the resurgence in multifactor productivity growth in the post-1995 period has yet to surpass the pre-1973 performance, more rapid multifactor productivity growth occurred in the last part of the 1990s.

1.4 Conclusion

This paper has documented the evolution of the sources of economic growth of the Canadian business sector. It finds that the growth in output of the Canadian business sector in the post-1995 period has been substantially above the earlier part of the decade and of the previous decade. In addition, after almost two decades of lacklustre performance, the productivity statistics, beginning in 1995, have begun to reveal the impact of increasing capital formation in ICT technologies. Progress in ICT is driving down relative prices of computers, software, and communication equipment and inducing investment in these assets by firms (12.2% per year growth on average during the 1981-2000 period).

The paper also examines the pattern of growth in capital services in terms of both quantity and quality components. It distinguishes between capital quantity growth due to investment, and capital quality growth due to substitution between different types of capital assets. Much of the recent investment boom has been associated with substitution across assets as the relative price of high-tech assets steadily fell. Capital 'quality' grew over the 1981-2000 period at 1.2% per year on average, of which 75% was due to changes within asset classes.

In terms of the sources of the 3.3% annual average growth over the 1981-1988 period, capital input contributed 1.4% per year (0.6% for quality and 0.8% for capital quantity), labour input contributed 1.7% per year (1.2% for hours and 0.5% for labour quality). This is somewhat similar to the 1995-2000 period, when capital input at 1.7% contributed less than labour input at 2.2% per year to output growth.

In both countries, ICT is the largest contributor to growth within capital services, during the late 1990s, followed closely by structures in Canada. But the contribution of ICT in Canada is lower than in the U.S.

What is even more remarkable about the post-1995 period, compared to the previous periods, is the recovery in the multifactor productivity performance, posted at 1.0% per year in Canada and 1.3% in the U.S. (compared to 0.2% and 1.0%, respectively, for the 1981-1988 period).

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2

An Alternative Methodology for Estimating Economic Depreciation: New Results Using a Survival Model

Guy Gellatly, Marc Tanguay and Beiling Yan

2.1 Introduction

Studies of asset depreciation are illuminating, in part, because they enable national accountants to better characterize the evolution of an economy's productive capacity. Base indicators of economic performance, such as multifactor productivity estimates, depend on the growth of the economy's stock of capital assets. In the standard perpetual inventory framework, the stock of capital available to economic agents in any current period is simply the sum of current investment and cumulative net investment in past periods (i.e., gross accumulated capital stock less depreciation). Different depreciation profiles can affect how this cumulative stock of capital is discounted, and may give rise to discordant statistical impressions of how productively the economy is transforming inputs into outputs.

An equally illuminating vantage point to evaluate the impact of asset depreciation is by studying its effect on investment behaviour. Commenting on the consequences of the rules used for tax depreciation, Hulten and Wykoff (1981, p. 82) make the observation that "depreciation lives, without some factual basis, can lead to potentially serious distortions in the incentives to invest in various types of assets." Depreciation, and perceptions thereof, have substantial impacts on the economic system.

This chapter uses new micro-level data on used-asset prices to estimate patterns of economic depreciation. We develop depreciation profiles and life estimates for 25 different machinery and equipment assets and 8 structures. As a final exercise, we use our estimation framework to produce perpetual inventory estimates of the capital stock. At various stages of the analysis, we compare our econometric results that are derived *ex post* from price information to a range of *ex ante* results based on estimates of service life and geometric accounting techniques.

Our principal objectives in this chapter are, first, to develop a more comprehensive profile of how asset values decline at different stages of service life, and second, to ask whether the existing stock of techniques and assumptions, commonly used to produce geometric estimates of asset depreciation, accords with actual market outcomes. Our econometric results are based on a rich database that contains detailed price and age information on over 25,000 individual assets.

New estimates aside, much of the value-added herein is, in our view, methodological. Our estimation framework differs significantly from earlier studies in that we model changes in asset value using estimation techniques that fall under the rubric of survival analysis. Our final results are based on a Weibull maximum likelihood survival model that has been modified to produce estimates of depreciation. Our framework evaluates whether rates of depreciation are age-invariant (i.e., consistent with geometric accounting techniques) or variable at different stages of service life.

The structure of the chapter is as follows. Section 2.2 reviews a range of theoretical and empirical issues that motivate our study. Particular emphasis is placed on the use of constant-rate geometric estimates of economic depreciation that form the basis for perpetual inventory estimates of capital stock. We discuss the properties of our data sample in Section 2.3. We develop our econometric model in Section 2.4. Results are presented in Section 2.5. Estimates of capital stock based on a constrained (exponential) version of our Weibull depreciation model are evaluated in Section 2.6.

2.2 Theoretical Foundations

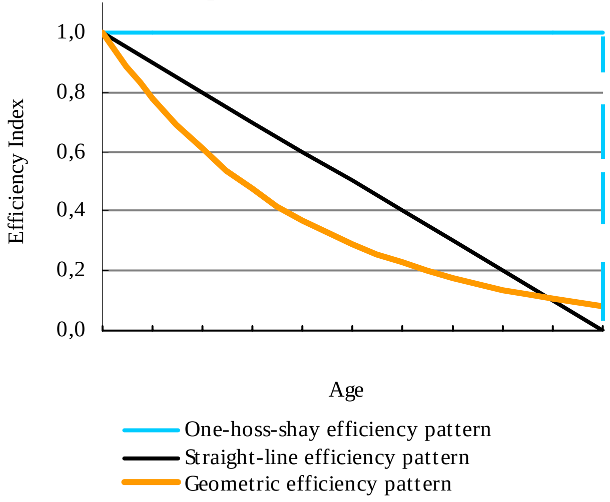
2.2.1 Efficiency and Depreciation

As economic concepts go, depreciation is ubiquitous. A central characteristic of any system of production, depreciation, in its most common usage, refers to how the elements of an economic system erode with age. When it is desirable to do so, economic agents respond to this decline in productive capacity by reinvesting—businesses, in replacement technologies or plants and equipment; governments, in infrastructure and other public goods. These examples invoke images of depreciation as an observable, physical process, one that describes the rate at which productive assets are ingested, and dictates the pace of offsetting investments in maintenance and replacement.

Given that popular notions of depreciation are often beset by the above imagery, precise working definitions need to be set out at the onset. In particular, care must be taken to distinguish *physical, or capacity*, depreciation from *economic depreciation*. The crucial distinction between these two types rests with *what* is eroding or decaying—the production capabilities of the asset itself, or its subsequent economic value.

To make this distinction, we start by focusing on the evolution of an asset's productive efficiency, that is, its ability to produce goods and services over the course of its service life. As the asset experiences wear and tear, its productive efficiency declines, and it undergoes a process of physical depreciation. One can envisage this process in a stylized framework by imagining a multi-period revenue stream that is directly proportional to the asset's productive capacity. We represent this process graphically using the set of efficiency profiles depicted in Figure 2.1.

Figure 2.1
Comparative Efficiency Profiles



Following Hulten and Wykoff (1981), we consider three common efficiency profiles, beginning with the one-hoss-shay.[1] Assets with

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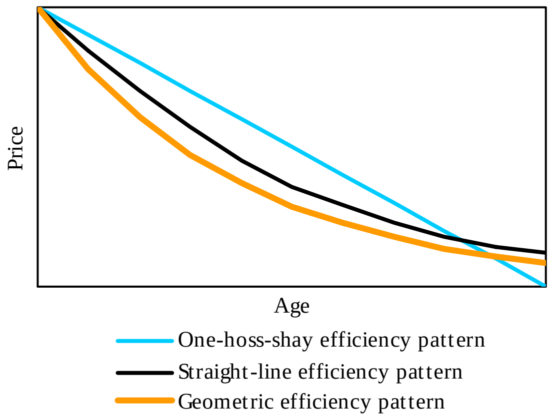
[1] Much of this comes directly from Hulten and Wykoff (1981).

one-hoss-shay efficiency profiles undergo no physical depreciation over the course of their productive lifecycle. They retain their full ability to produce goods and services, and generate a constant stream of in-period revenue up until the end of their service life. Other assets may exhibit a straight-line efficiency profile, wherein their productive capacity, and in-period revenues, decline in progressive linear increments over their lifecycle. A final class of assets may exhibit geometric decay, yielding a convex-to-the-origin efficiency profile. This is an example of an accelerated pattern, in which declines in efficiency are more pronounced in earlier periods of service life than in later periods.

Figure 2.2
Corresponding Depreciation Profiles



We now turn to consider economic depreciation, defined as the decline in asset value (or asset price) associated with aging (Fraumeni, 1997). This price decline reflects, in the first instance, the reduction in present value that occurs over a finite service life. Other things equal, an older asset has less opportunity to generate revenue than a younger asset—which reduces the economic value of the former. This decline in asset value will be accelerated if aging is accompanied by a loss of productive efficiency, as all capital assets that suffer wear-and-tear can be expected to return a lower stream of benefits in any single period. In Figure 2.2, we examine the patterns of economic depreciation that correspond to the efficiency profiles presented in Figure 2.1.[2]

The decline in present value is most clearly seen in the one-hoss-shay case. In the simplest of worlds, one-hoss-shay efficiency profiles will give rise to linear depreciation patterns, as older assets, while still generating the same in-period revenue as their younger counterparts, are worth progressively less in each period.[3] This "general non equivalence" between asset efficiency and asset value is also apparent in the straight-line case. Linear efficiency profiles do not give rise to linear depreciation curves; rather, asset values follow a more accelerated pattern with higher losses in value earlier in service life. Geometric patterns represent the lone exception to this general nonequivalence—as one can here move interchangeably between a geometric "efficiency" framework and a geometric "value or price" framework with reductions in efficiency that mirror concomitant reductions in price.[4]

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[2] Stylized relationships between asset efficiency and depreciation are generally predicated on two sufficient conditions—first, that service lives and efficiency patterns are known with certainty, and second, that an asset's price reflects the actualized value of its future stream of revenues where these revenues are a linear function of the capacity of the asset.

[3] We depict a linear depreciation profile here simply to illustrate the incremental decline in present value as the asset progresses through its service life. Note, however, that the depreciation curve corresponding to a one-hoss-shay efficiency profile will not be linear if (i) the duration of service life is not known with certainty, or (ii) the value of the asset's productive capacity is discounted in future periods. Hulten and Wykoff (1981) depict a concave-to-the-origin depreciation profile for assets with one-hoss-shay efficiency characteristics.

[4] Once again, this efficiency-price relationship is conditional on several factors; see note 2.

These heuristic examples are worth stressing in view of Hulten and Wykoff's (1981, p. 90) observation that relationships between efficiency and depreciation represent "the most misunderstood relationship in all of depreciation theory." The requirement that national accountants adopt a consistent treatment of efficiency and economic depreciation has been voiced, more recently, by Jorgenson (1994). At issue is the extent to which rates of economic depreciation can be adequately used to proxy rates of physical replacement when making perpetual inventory estimates of capital stock.

Our principal focus herein is with economic depreciation—the reduction in price or value associated with aging. Aging, however, is not equivalent to use, though we have tacitly treated it as such in the above examples. Asset values decline due to wear-and-tear and the reduction in present value as assets work their way through economic systems. Following Fraumeni (1997), changes in asset value are also driven by a continual process of "revaluation", that is, reductions in the value of older assets from period-to-period owing *inter alia* to increased obsolescence. There is an economic cost to holding older assets if new assets—assets that embody recent technological innovations—can lead to superior performance. Theoretical models of economic depreciation will often distinguish between the price effects of use and obsolescence, as it is not difficult to imagine circumstances in which the relative weight of the latter is a more significant determinant of overall price movements. Personal computers may undergo relatively little physical depreciation over their service life, and yet they may experience large declines in resale value due to the rapid onset of obsolescence.

Herein, we treat aging and obsolescence as basic determinants of the same process—in that both effect changes in the price of an asset over its lifecycle. This is consistent with the approach taken by statistical agencies when developing estimates of depreciation for systems of national accounts (Fraumeni, 1997).

2.2.2 Straight-line and Geometric Forms

In this section, we draw attention to two specific forms of depreciation: straight-line and geometric. While much of our analytical interest rests with the latter, straight-line depreciation is a useful starting point, and is applied extensively in a national accounting framework.

The simple algebra of straight-line and geometric depreciation is outlined by Fraumeni (1997). We present much of her discussion below.

Straight-line patterns assumes equal dollar value depreciation at all stages of an asset's lifecycle. Per-period depreciation for a dollar of investment takes the form

$$D = \frac{1}{L} \tag{1}$$

where L is service life. Although the dollar loss is equal from period-to-period, the rate of depreciation—that is, the percent change in asset value from period-to-period—increases progressively over the course of an asset's service life. For a marginal dollar of investment, this rate is

$$\delta_i = \frac{1}{L-(i-1)}\text{, for all periods } i=1,\ldots,L. \tag{2}$$

Geometric depreciation represents the conceptual counterpoint to the straight line case. Geometric profiles hold the *rate* of depreciation, not the period-to-period dollar amount, fixed over the course of an asset's service life. Geometric profiles are accelerated—with higher dollar depreciation in early periods—giving rise to the convex age-price profile depicted in Figure 2.2. Per-period depreciation is defined as

$$D_i = \delta(1-\delta)^{(i-1)} \tag{3}$$

where δ is the constant (age invariant) rate of depreciation.

The majority of empirical research on asset depreciation has concentrated on the geometric form. In early studies, geometric patterns were often assumed. Evidence that geometric rates are generally appropriate for a wide range of asset types is found in Hulten and Wykoff (1981) and Koumanakos and Hwang (1988).[5] In practice, geometric rates are analytically expedient in two important respects: (1) they can be estimated indirectly via accounting methods; and (2) their constant-rate property allows them to be used as a proxy for the replacement rate in standard perpetual inventory models of capital stock. We address the first of these points below.

Direct estimates of δ generally require information on resale prices. In the absence of sufficient price information, geometric rates can be calculated indirectly as

$$\delta = \frac{DBR}{L} \tag{4}$$

where DBR is a (constant) declining-balance rate and L is service life. The value of the declining balance rate determines, other things equal, the extent to which asset values erode more rapidly early in the lifecycle (Fraumeni, 1997). Higher values of the declining balance rate bring about higher reductions in asset value earlier in service life, giving rise to more convex (i.e., accelerated) depreciation profiles.[6] The indirect rate of depreciation produced by equation 4 is *ex ante* in the sense that the value of the *DBR* is set to some fixed constant *a priori,* and because the estimates of L are generally based on *ex ante* expectations of service life. Estimates of L have traditionally come from experts in the field or from tax codes. In Canada, service life estimates have been derived from the expectations of survey respondents regarding an asset's useful life.

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[5] For a survey of the empirical literature, see Fraumeni (1997); for a discussion of empirical methods, see Jorgenson (1994).

[6] The concept of a finite service life, however, is not particularly well suited to the geometric case. To see this, note that service life *L* is not finite, in the same sense that it can be considered finite in the straight-line case. Straight-line patterns depreciate at a constant dollar amount until the economic value of an asset is exhausted, that is, up until the point of retirement. In contrast, the geometric patterns given by equations 3 and 4 are infinite in that some (progressively declining) portion of asset value continues to survive *after* service life *L*. This "surplus" or remaining asset value is not necessarily trivial. Consider a hypothetical asset which has a mean service life of 25 years. If we base our estimates of geometric depreciation on the double-declining balance rate (DBR=2), 13.5% of asset value survives beyond the mean retirement age. This "infinite" characteristic of geometric forms has occasioned the use of truncation techniques which adjust depreciation estimates upwards in order to exhaust total asset value at service life *L*.

There has been considerable debate over whether the assumptions embodied in the calculation of geometric rates are empirically appropriate. Some researchers have questioned whether the heavy losses in asset value that are often observed early in asset life are consistent with constant, geometric rates. It should be stressed that constant rates do not, in and of themselves, preclude highly accelerated depreciation profiles; rather, the issue is simply whether these rates are, on net, sensible representations of the change in asset value in *every* period. A key aspect of this debate centers on defining an appropriate value for the declining balance rate. Even if constant-rate, geometric age-price profiles are empirically justified, the choice of particular values for *DBR* and *L* is still at issue. Much concern rests with the presumed *ad hoc* nature of the declining-balance rate *DBR*. While estimates of service life *L* often derive from expert sources, assumptions about the declining-balance rate are, at first blush, less transparent.

Double-declining balance rates (*DDBR*)—which set the value of the *DBR* equal to 2—have been extensively used in practice. In their estimates of capital stock, Christensen and Jorgenson (1969) employ double-declining balance rates to estimate rates of economic depreciation. Statistics Canada's productivity program has historically based its estimates of geometric depreciation on a double-declining rate. One advantage of the *DDBR* is that it provides a "conceptual bridge" back to the straight-line case, anchoring the midpoints of these depreciation schedules at an equivalent age point. To see this, we can examine a simple measure of central tendency. Using the *DDBR*, the midpoint of the geometric curve is

$$\mu = \frac{1}{\delta}\text{, or equivalently from equation 4,} \tag{5}$$

$$\mu = \frac{L}{DBR} = \frac{L}{2} \tag{6}$$

while $\frac{L}{2}$ also represents the midpoint of the depreciation schedule in the straight line case.[7] Recent estimates of geometric depreciation used by the U.S. Bureau of Economic Analysis assume a lower value for the declining balance rate for many individual assets (*DBR*=1.65 for machinery and equipment and 0.91 for structures). Based on the empirical research of Hulten and Wykoff (1981), these values will, other things equal, produce lower rates of geometric depreciation than the double-declining case.

The basis for the Hulten-Wykoff estimates of the *DBR* warrant some discussion here. In a study for the Office of Tax Analysis of the U.S. Department of the Treasury, the authors generate direct estimates of geometric depreciation for a large variety of assets based on samples of used-asset prices, and then base subsequent estimates of δ (for assets for which no price information was available) on the geometric accounting method described by equation 4. This two-stage procedure enabled the authors to produce a set of depreciation estimates that was consistent with the asset classes used by the U.S. National Income and Product Accounts. To produce geometric rates of depreciation from equation 4, Hulten and Wykoff calculated average values for the declining balance rate *DBR* using their price-based estimates of δ and exogenous information on service life. This yielded average *DBR* values of 1.65 for machinery and equipment and

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[7] For an overview of the geometric distribution, see Hastings and Peacock (1975).

0.91 for structures—average *DBR* values based on asset categories for which price information was directly available.[8] In cases where no price information was available, the authors then combined these estimates of *DBR* with asset-specific information on service life L to produce indirect estimates of δ .[9]

One advantage of our study is that we can ask whether *ex ante* depreciation rates that derive from a geometric accounting framework are consistent with the *ex post* rates produced by our econometric models. We examine this in Section 2.5 by asking whether summary measures of asset life from our econometric estimates of depreciation (which derive from price information collected over an 11 year period) are consistent with recent survey evidence on asset life which can be used to estimate δ via equation 4.

2.3 Data Source

The data used for this study come from Statistics Canada's annual *Capital and Repair Expenditures Survey*, an establishment-based survey in which respondents are asked to report on their sales and disposals of fixed assets. Respondents to the survey operate in a broad mix of goods and services industries. The survey provides detailed information on asset type, gross book value, sale price, and age. Our data set was constructed by merging a series of cross-sectional survey frames, creating a database on used-asset prices that covered an 11 year reporting period (1985-1996).

The sample used for our analysis was generated in several stages. Our initial base sample had 53,802 observations on 240 separate assets. Many of these observations, however, could not be used due to data limitations. We first removed observations that were missing information on age and/or initial book value. These observations comprised 43% of the initial base sample. We then excluded institutional assets from our sample (e.g., schools, hospitals, universities). This reduced our dataset to 30,235 observations on 119 assets. To ensure that our econometric estimates are robust, we restricted our analysis to individual assets with more than 100 observations. This further reduced our sample of usable observations to 28,089 observations on 33 assets.

A final stage of our editing strategy was to review the sample for outliers. To ensure consistency across asset types, we adopted systematic rules for outlier identification. We describe our technique for identifying and eliminating outliers in Appendix 2.A. Our final analysis file contains over 25,000 usable observations on 33 individual assets, covering two asset classes: structures and machinery and equipment. We review the characteristics of the final sample in Table 2.1.

Studies that use market prices to estimate depreciation profiles must address issues of data reliability.[10] Traditionally, used-asset samples have not contained information on retirements, which, in turn, biases the estimation of depreciation profiles. In their 1981 study, Hulten and Wykoff controlled for retirements by weighting their price data by survival probabilities. Methodological adjustments of this sort are not required herein, as information on discards is included directly in our database.

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[8] As Hulten and Wykoff (1981) note, the asset categories for which they were able to calculate depreciation rates directly from price information represent a substantial share of total NIPA investment expenditures—42% of investment in non-residential structures and 55% of investment in producers' durable equipment.

[9] For a useful discussion of the Hulten-Wykoff methodology, see Fraumeni (1997).

[10] Once again, for a general discussion of these issues, see Fraumeni (1997).

Table 2.1 Data Sample

Asset Code	Number of Observations	Description
1001	791	Plants for Manufacturing
1006	268	Warehouses, Refrigerated Storage, Freight Terminals
1008	151	Maintenance Garages, Workshops, Equipment Storage Facilities
1013	626	Office Buildings
1016	202	Shopping Centers, Plazas, Malls, Stores
1099	168	Other Industrial and Commercial
3002	162	Telephone and Cablevision Lines, Underground and Marine Cables
3003	128	Communication Towers, Antennae, Earth Stations
6001	2,651	Office Furniture, Furnishings (e.g., desks, chairs)
6002	2,484	Computers, Associated Hardware and Word Processors
6003	875	Non-Office Furniture, Furnishings and Fixtures (e.g. recreational equipment, etc.)
6004	871	Scientific, Professional and Medical Devices
6005	365	Heating, Electrical, Plumbing, Air Conditioning and Refrigeration Equipment
6006	124	Pollution Abatement and Control Equipment
6007	118	Safety and Security Equipment (including firearms)
6009	571	Motors, Generators, Transformers, Turbines, Compressors and Pumps of all types
6010	596	Heavy Construction Equipment (e.g., loading, hauling, mixing, paving, grating)
6011	459	Tractors and Other Field Equipment (truck tractors - see 6203)
6012	707	Capitalized Tooling and Other Tools (hand, power, industrial)
6013	127	Drilling and Blasting Equipment
6201	2,554	Automobiles and Major Replacement Parts
6202	204	Buses (all types) and Major Replacement Parts
6203	3,086	Trucks, Vans, Truck Tractors, Truck Trailers and Major Replacement Parts
6205	207	Locomotives, Rolling Stock, Street and Subway Cars, Other Rapid Transit and Major Parts
6206	104	Ships and Boats and Major Replacement Parts
6207	223	Aircraft, Helicopters, Aircraft Engines and Other Major Replacement Parts
6299	209	Other Transportation Equipment
6402	539	Computer-assisted Process for Production Process
6403	267	Computer-assisted Process for Communication and Related Equipment
6601	1,001	Non-computer Assisted Process for Material Handling
6602	2,918	Non-computer Assisted Process for Production Process
6603	595	Non-computer Assisted Process for Communication and Related Equipment
8999	745	Other Machinery and Equipment (not specified elsewhere)

A second concern with used-asset prices rests with Ackerlof's (1970) "lemon's hypothesis". According to this view, assets sold in resale markets are inferior to those that owners retain for production. In practice, variants of the lemons hypothesis are all predicated on the existence of information asymmetries between buyers and sellers. The extent to which lemons issues limit the utility of used-asset studies is dependent *inter alia* upon one's preconceptions about the ability of markets to solve information problems. For instance, the emergence of market intermediaries that provide used-asset information to prospective buyers will reduce the severity of these information asymmetries. In addition, the existence of different market segments, corresponding to different quality types, also reduces the impact of lemons problems. Herein, we align ourselves with the orthodox position—and take the view that used-asset prices can tell us much about economic depreciation. We should stress that our edit strategy eliminates some of the more apparent lemons—observations with extremely low resale values, relative to like assets, early in service life.

Finally, concerns over representativeness often come to the fore when results are based on small samples. Hulten and Wykoff (1981) and Koumanakos and Hwang (1988) notwithstanding, much of empirical work on asset depreciation has been based on small samples for limited numbers of assets. Herein, our database confers certain advantages, as we were able to amass a large and diverse set of price information based on a comprehensive annual investment survey taken by Canada's national statistical agency.

2.4. Estimation Framework

2.4.1 Survival Ratios and Weibull Distributions

As Jorgenson (1994, p. 1) observes, "the challenge facing economic statisticians" engaged in research on economic depreciation "is to employ asset-price information effectively." Econometric studies that use vintage prices to estimate depreciation curves build on the pioneering work of Hall (1971) and Hulten and Wykoff (1981). Hall introduced an analysis of variance model in which prices were estimated as a function of age- and time-specific dummies. A major contribution of Hall's model is the estimation of nonlinear time and age effects.[11] Hulten and Wykoff extended econometric (and nonlinear) research on depreciation schedules by utilizing a Box-Cox model which tests for the appropriateness of various functional forms (rectangular, straight-line, and geometric). Koumanakos and Hwang (1988) applied this Box-Cox approach to their analysis of Canadian assets using 1987 data on used-asset prices.

Our estimation approach differs from earlier research on asset depreciation in that we model changes in asset value using survival analysis methods. Our basic unit is a survival ratio, observed at some age *t*. For all observations i in our sample, we calculate this *survival ratio* as

$$R_i = \frac{SP_i}{GBV_i} \tag{7}$$

where *SP* is the selling or discard price of the asset at age *t*, and *GBV* is its gross book value. Both numerator and denominator are expressed in constant dollars with the selling price *SP* deflated in the survey year, and *GBV* in the asset's initial year of its service life. R_i is thus the share of asset value that remains when the asset is sold at some reported age *t*. If the asset has been retired without a sale, R_i equals 0, corresponding to a zero selling price.

Our estimation model posits that changes in asset value can be modeled using a Weibull distribution. A two-parameter distribution, survivor and hazard functions for the Weibull are defined as

$$S(t) = \exp[-(\lambda t)^{\rho}], \text{ and} \tag{8}$$

$$h(t) = \lambda\rho(\lambda t)^{\rho-1} \tag{9}$$

where ($\lambda > 0$) and ($\rho > 0$).

Extensively used in duration analysis, the Weibull distribution is a flexible parametric form that can be readily integrated into a depreciation framework. Weibull formulations allow for variable, age-variant rates of depreciation, but can be restricted to produce constant (exponential) rates that are directly comparable to the geometric rates

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[11] A more thorough review of the empirical work noted here—particularly Hall (1971) and Hulten and Wykoff (1981)—is found in Jorgenson (1994). Our discussion here is by no means exhaustive. For a more comprehensive review, see Jorgenson (1994) and Fraumeni (1997).

commonly used in depreciation accounting. Accordingly, then, we can place our estimation framework, for comparative purposes, squarely within the geometric orthodoxy.

In what follows, we develop three different econometric specifications for our Weibull survival model.

2.4.2 OLS Average-price Weibull Model

We begin the development of our estimation framework by introducing a simple linear version of our survival model. This represents, in effect, a base specification that we use strictly for comparative purposes.

Taking the natural logarithm of the Weibull survivor function (equation 8) and multiplying by (-1) yields:

$$-\log(S) = (\lambda t)^{\rho}\,. \tag{10}$$

Transforming this into linear form, we have

$$\log[-\log(S)] = \rho[\log\lambda + \log t]\,. \tag{11}$$

Accordingly, an OLS regression of the form

$$y = a + bx + u \tag{12}$$

will yield estimates of the Weibull parameters where

$$\lambda = \exp(a/\rho) \text{ and} \tag{13}$$

$$\rho = b\,.^{12} \tag{14}$$

In standard survival analysis models, the estimation of equation 12 is often based on nonparametric estimates of the survivor function, which derive from empirical estimates of the hazard rate (the ratio of events to the total population at risk at each age t). Kaplan-Meier survivor function estimates are commonly used for this purpose.[13]

Our estimation framework differs from standard survival applications in that we are interested in modelling changes in asset value, as opposed to the existence of the asset itself.[14] Changes in valuation (i.e., depreciation) occur incrementally over all stages of service life, as opposed to instantaneously at some age t. In this sense, the individual survival ratios in our asset samples R_i depict a concept of cumulative loss, rather than some instantaneous, or discrete, reduction in asset value. Consequently, these individual price ratios are not, in strict conceptual terms, consistent with the type of events that generate an empirical hazard—all of which occur discretely at some age . For this reason, we estimate equation 12 using a weighted average-price calculated independently

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[12] For a useful discussion, see Lawless (1982).

[13] For background on this technique, see Kiefer (1988).

[14] We address the issue in much greater detail when developing our maximum-likelihood survival model in Section 2.4.3.

at each point in an asset's age distribution. Taken together, these average prices trace out the coordinates of an aggregate age-price profile. This weighted average is

$$\bar{R}(t) = \frac{\sum SP_i}{\sum GBV_i}. \qquad (15)$$

The dependent variable in our linear model is obtained by substituting the above average price expression (equation 15), effectively an average survival ratio, for the term on the left-hand side of equation 11. The right-hand side variable in equation 11 is just log age. Once the OLS parameters have been transformed into Weibull parameters (equations 13 and 14), the depreciation profile is generated by plotting solution values for the survivor function (equation 8). This depreciation curve is a locus of probability estimates, giving the share of asset value that survives beyond each age *t*.

We can generate an exponential (constant-rate) variant of this model simply by restricting the value of the Weibull parameter ρ. When ρ equals unity, the rate of depreciation occurs at a constant rate—defined by the exponential hazard rate λ. This rate represents the linkage between our survival framework and the geometric accounting methods described by equation 4, as the exponential distribution is simply the continuous-time version of the geometric. To see this, note that geometric depreciation can be expressed as $\left(1-\frac{\lambda}{m}\right)^{mt}$ where *t* represents age, λ is the rate of depreciation and *m*, the frequency at which this rate is extracted from the original value within the period (this is equivalent to the compounding period). This geometric distribution tends to the exponential when the compounding frequency becomes instantaneous. That is,

$$\lim_{m\to\infty}\left(1-\frac{\lambda}{m}\right)^{mt} = e^{-\lambda t}.\,[15] \qquad (16)$$

It is worth stressing that, issues of conceptual appropriateness aside, the estimation of equation 11 via full samples of individual prices is problematic. Large numbers of observations in our asset samples are discards—observations with a 0 value for R_i due to a reported 0 selling price. Since the transformation from equation 8 to equation 11 requires positive prices, zero prices would have to be replaced by some nominal, positive decimal value. But the subsequent LS estimates would be biased due to density accumulation on this point. In a (naturally) linear model, Tobit-style adjustments can be made to remove this bias.[16] However, in our case, the linear estimation model has been transformed, rendering the point of density accumulation undefined.

The estimation of equation 11 via weighted average-prices entails significant losses of sample information. The case of computers is illustrative. A relatively short-lived asset, price information exists for only 17 years. Accordingly, depreciation estimates from the linear average-price model are based on summary price information described by 17 sample points. Yet, as reported in Table 2.1, almost 2,500 individual observations exist

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[15] For discussion, see Silverberg (1990).

[16] See Greene (1981).

for computers. In what follows, we develop a micro-estimation framework that generates depreciation profiles from this and other asset samples directly.

2.4.3 Maximum-likelihood Survival Model

We begin by considering asset valuation within the standard maximum-likelihood framework.

Let y define a dummy variable describing the two possible life states for a given asset, and let

$y=1$ when the asset is dead or retired (its sale value equals zero)

$y=0$ if otherwise.

The likelihood of an observation $l(t)$ is

$$l(t) = f(t)^{y} S(t)^{(1-y)} \tag{17}$$

where $f(t)$ is the density function, and $S(t)$ the survival function.[17]

Equation 17 is best applied to situations in which the event being modelled can be described using binary life states (e.g., "completely" alive or "completely" dead). If the asset is "dead", the likelihood function reduces to the density function, and gives the probability of death at age t. If the asset is still "alive", the likelihood reduces to the survival function, and gives the probability that it survives until t. The log-likelihood of observing a sample of n observations then takes the form

$$\ln L = \sum_{i=1}^{n} \left[y_i \ln f(t_i) + (1 - y_i) \ln S(t_i) \right]. \tag{18}$$

We now modify equation 18 based on our set of observed survival ratios R_i (defined previously by equation 7) which describe the extent to which the asset is alive or dead. These price ratios are continuous, not binary, and can take on any value in the open set (0,1). Accordingly, each observation in the sample simultaneously represents two pieces of information: R_i, the portion of asset value that survives at some age t, and $1 - R_i$, the portion of asset value lost at t. The log-likelihood of a sample of n observations becomes

$$\ln L = \sum_{i=1}^{n} \left[(1 - R_i) \ln f(t_i) + R_i \ln S(t_i) \right]. \tag{19}$$

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[17] This is consistent with the standard model of survival. See for example, Cox and Oakes (1984) and Wayne (1982).

The log likelihood formulation given by equation 19 has an intuitive interpretation. R_i, the price ratio, represents the amount of asset value that survives to some age t, multiplied by a corresponding survival probability $S(t_i)$, while $1-R_i$ represents the amount of value lost, multiplied by its failure probability $f(t_i)$.

While well suited to many survival applications, equation 19 needs to be modified in order to produce estimates of economic depreciation. The issue rests with the use of the standard density formulation $f(t_i)$ as a sensible probability concept when modelling the (continuous) loss of asset value. By specifying a density term, the above equation assumes that asset values remain unchanged in all periods prior to the point of transaction, that is, prior to being sold or retired. Embedded, then, in equation 19 are depreciation profiles that are conceptually similar to a "one-hoss-shay"—with asset values remaining at their maximum survival ratio prior to some age period (the point of transaction *t*) at which some partial or total loss in value is observed.

We can modify equation 19 to adjust for continuous depreciation by replacing the density term $f(t_i)$ with the cumulative density $F(t_i)$. While the density term $f(t_i)$ assumes that the loss in asset value occurs at t, the cumulative density $F(t_i)$ assumes that reductions in value occur *before* time t.

Our estimation equation becomes

$$\ln L = \sum_{i=1}^{n} \left[(1-R_i)\ln F(t_i) + R_i \ln S(t_i) \right] \tag{20}$$

where $F(t_i)$ is the probability that asset values will decline at some point prior to t.[18] To estimate the above model using the Weibull distribution, we express the cumulative density $F(t_i)$ and survivor function $S(t_i)$ as

$$S(t) = \exp[-(\lambda t)^{\rho}] \tag{21}$$

$$F(t) = 1 - \exp[-(\lambda t)^{\rho}]. \tag{22}$$

Once again, restricting the parameter ρ will produce the exponential or continuous-time geometric version of the model with the survivor and cumulative density functions

$$S(t) = \exp(-\lambda t) \tag{23}$$

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[18] This is similar to binary response models where the level of response (time) is observation specific. Our formulation resembles one of the prototypes listed by Lagakos (1979)—in which observations share a common survival distribution, but different censoring experiences. In our framework, the likelihood function is both left- and right-censored, and the usual indicator variable y is replaced by a survival ratio R_i.

$$F(t) = 1 - \exp(-\lambda t)\,. \qquad (24)$$

Estimation of equation 20 based on individual survival ratios R_i assumes that depreciation schedules are not correlated with the size—or dollar value—of the asset. To account for dollar value differences across observations, we weight each observation by its share of total asset value, multiplied by the number of observations in the asset sample.[19] Denoting this weight as w_i, we can rewrite equation 20 as

$$\ln L = \sum_{i=1}^{n} w_i \left[(1 - R_i) \ln F(t_i) + R_i \ln S(t_i) \right]. \qquad (25)$$

2.4.4 Adjusting our Depreciation Model to Allow for Patterns of Digit Preference

For many of the asset samples, survey respondents exhibited patterns of digit preference. This is evidenced by relatively high numbers of observations clustered at five-year intervals. These patterns of age-rounding can affect the estimation of our model. Accordingly, we derive an alternative version of our ML survival model (equation 25) that takes digit preference into account.

If age-rounding is apparent, the true age of the asset t^* at the time of transaction (sale or discard) is observed with some rounding error. If we assume that t^* falls within some upper and lower age bound, we can express the likelihood function as

$$\ln L = \sum_{i=1}^{n} w_i \left[(1 - R_i) \ln F(UB) + R_i \ln S(LB) \right]. \qquad (26)$$

Equation 26 requires some explanation. Although the portion of the likelihood function that defines the loss in asset value cannot be measured with certainty at age t^*, it is sensible to assume that this decline occurs prior to some unknown upper bound age UB (where $UB > t^*$). Conversely, for the portion of the likelihood function that corresponds to survival, we assume that asset value survives beyond some unknown lower bound age LB (where $LB < t^*$).

We can operationalize these concepts using a series of (0,1) dummy variables that correspond to discrete points in the age distribution where rounding is likely to occur. Let δ be a dummy variable which takes a value of 1 when there is a rounding problem, 0 if otherwise. Let $\sigma_5, \sigma_{10}, \sigma_{15}, \sigma_{20}$ represent the presence of this problem respectively at ages 5, 10, 15 and 20. This results in four intervals, each with a lower and an upper bound, with eight corresponding parameters. We can simply this framework for the purpose of estimation. First, we assume that there is no systematic rounding error. This enables us to center the intervals on the rounded values—which reduces the number of estimated parameters from 8 to 4. Second, we assume that adjacent bounds are equal

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[19] Accordingly, the sum of the weights is equal to the total number of observations. No artificial degrees of freedom are created.

between interval spaces.[20] If there are 3 adjacent areas, this reduces the number of required parameters from 4 to 1.[21]

The log-likelihood of a sample of n observations adjusting for patterns of digit preference becomes

$$\ln\ L = \sum_{i}^{n} w_i \begin{bmatrix} (1-\delta)_i \left[(1-R_i)\ln F(t_i) + R_i \ln S(t_i)\right] + \\ \delta_i \left[\sum_{r=5,10,15,20}^{20} \sigma_r \left((1-R_i)\ln\left(F(UB_r)\right) + R_i \ln(S(LB_r))\right) \right] \end{bmatrix} \tag{27}$$

where $F(t_i)$ and $S(t_i)$ represent the Weibull cumulative density and survival functions.[22]

We now have three variants of our Weibull survival model: the OLS average-price model (equation 11), the ML survival model without corrections for digit preference (equation 25) and the ML survival model with corrections for digit preference (equation 27).

2.5 Empirical Results

2.5.1 Comparative Survival Models

In tables 2.2 and 2.3, we report depreciation profiles for assets in our sample based on each of the three econometric methods outlined above. Each depreciation profile is represented as a locus of survivor function estimates (SFEs) corresponding to different stages of the asset's lifecycle. Accordingly, individual SFEs represent the portion of total asset value that survives beyond *t*. For individual assets in the structures class, we report SFEs for the first five years of life, and then at discrete 5 year intervals, covering ages 10 through 25. Our objective here is to examine depreciation profiles at both early and late stages of the lifecycle, in light of *a priori* expectations that assets in the structures class are more likely to exhibit relatively long service lives. For assets in the machinery and equipment class, we report SFEs continuously over the first ten years of service life.

Results in tables 2.2 and 2.3 are either unrestricted Weibull estimates (denoted as "W" in column 2) or restricted-Weibull, exponential estimates (denoted as "E")—depending upon which constitutes the optimal specification. In cases where the null of a constant, age-invariant (exponential) rate of depreciation was rejected, Weibull estimates are reported. In cases where the null could not be rejected, the restricted exponential (or continuous-time geometric) estimates are reported.

Our use of different estimation techniques (represented by equations 11, 25, 27) allows us to gauge the extent to which depreciation profiles are sensitive to different operational versions of our survival model. As discussed in Section 2.4, the average-price

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[20] This is consistent with the ordered response model. Equal interval space requires that the lower bound of an upper interval is equal to the upper bound of the interval directly below it.

[21] Functionally, we refer to this as the *MRE*—the magnitude of rounding error at age 5 and 15. LB_5, LB_{10}, LB_{15} and LB_{20}, the lower bounds of the intervals, can be defined as *5-MRE, 5+MRE, 15-MRE, 15+MRE* while UB_5, UB_{10}, UB_{15} and UB_{20}, the upper bounds, are *5+MRE, 15-MRE, 15+MRE* and *25-MRE.*

[22] Tests for specification and heterogeneity are discussed in Appendix 2.B.

Table 2.2 Ratio of the Residual Value: Machinery and Equipment

		Age of Assets									
Asset	Model	1yr	2yr	3yr	4yr	5yr	6yr	7yr	8yr	9yr	10yr
Office Furniture, Furnishings (6001)											
MLS (Eq. 27)	W	0.79	0.59	0.43	0.31	0.22	0.16	0.11	0.08	0.05	0.04
MLS (Eq. 25)	W	0.64	0.45	0.33	0.24	0.18	0.14	0.11	0.08	0.06	0.05
OLS (Eq. 11)	W	0.88	0.73	0.59	0.47	0.37	0.29	0.22	0.17	0.13	0.09
Computers, Associated Hardware and Word Processors (6002)											
MLS (Eq. 27)	W	0.56	0.31	0.18	0.10	0.06	0.03	0.02	0.01	0.01	0.00
MLS (Eq. 25)	E	0.56	0.32	0.18	0.10	0.06	0.03	0.02	0.01	0.01	0.00
OLS (Eq. 11)	E	0.67	0.45	0.30	0.20	0.14	0.09	0.06	0.04	0.03	0.02
Non-office Furniture, Furnishings and Fixtures (6003)											
MLS (Eq. 27)	W	0.89	0.75	0.61	0.49	0.38	0.29	0.22	0.17	0.12	0.09
MLS (Eq. 25)	E	0.80	0.64	0.51	0.41	0.33	0.26	0.21	0.17	0.13	0.11
OLS (Eq. 11)	E	0.81	0.66	0.54	0.44	0.36	0.29	0.23	0.19	0.16	0.13
Scientific, Professional and Medical Devices (6004)											
MLS (Eq. 27)	W	0.88	0.71	0.55	0.41	0.29	0.21	0.14	0.09	0.06	0.04
MLS (Eq. 25)	E	0.72	0.53	0.38	0.28	0.20	0.15	0.11	0.08	0.06	0.04
OLS (Eq. 11)	W	0.91	0.78	0.66	0.54	0.43	0.35	0.27	0.21	0.16	0.12
Heating, Electrical, Plumbing, Air Conditioning and Refrigeration Equipment (6005)											
MLS (Eq. 27)	E	0.77	0.59	0.45	0.34	0.26	0.20	0.15	0.12	0.09	0.07
MLS (Eq. 25)	E	0.74	0.54	0.40	0.29	0.22	0.16	0.12	0.09	0.06	0.05
OLS (Eq. 11)	W	0.89	0.75	0.60	0.46	0.35	0.26	0.19	0.13	0.09	0.06
Pollution Abatement and Control Equipment (6006)											
MLS (Eq. 27)	E	0.80	0.64	0.51	0.41	0.33	0.26	0.21	0.17	0.13	0.11
MLS (Eq. 25)	E	0.78	0.61	0.48	0.37	0.29	0.23	0.18	0.14	0.11	0.08
OLS (Eq. 11)	E	0.59	0.35	0.21	0.12	0.07	0.04	0.03	0.02	0.01	0.01
Safety and Security Equipment (6007)											
MLS (Eq. 27)	E	0.64	0.41	0.26	0.17	0.11	0.07	0.04	0.03	0.02	0.01
MLS (Eq. 25)	E	0.58	0.34	0.20	0.12	0.07	0.04	0.02	0.01	0.01	0.00
OLS (Eq. 11)	E	0.58	0.33	0.19	0.11	0.06	0.04	0.02	0.01	0.01	0.00
Motors, Generators, Transformers, Turbines, Compressors and Pumps of all types (6009)											
MLS (Eq. 27)	W	0.63	0.48	0.38	0.31	0.25	0.21	0.18	0.15	0.13	0.11
MLS (Eq. 25)	W	0.45	0.33	0.26	0.21	0.17	0.15	0.13	0.11	0.10	0.08
OLS (Eq. 11)	W	0.94	0.86	0.77	0.68	0.59	0.50	0.43	0.36	0.30	0.25

Table 2.2 Ratio of the Residual Value: Machinery and Equipment – *Continued*

		Age of Assets									
Asset	Model	1yr	2yr	3yr	4yr	5yr	6yr	7yr	8yr	9yr	10yr
Heavy Construction Equipment (6010)											
MLS (Eq. 27)	E	0.83	0.68	0.56	0.46	0.38	0.32	0.26	0.22	0.18	0.15
MLS (Eq. 25)	E	0.82	0.68	0.55	0.46	0.37	0.31	0.25	0.21	0.17	0.14
OLS (Eq. 11)	W	0.90	0.78	0.66	0.55	0.45	0.36	0.29	0.23	0.18	0.14
Tractors and Other Field Equipment (6011)											
MLS (Eq. 27)	E	0.82	0.68	0.56	0.46	0.38	0.31	0.26	0.21	0.18	0.15
MLS (Eq. 25)	E	0.83	0.69	0.58	0.48	0.40	0.33	0.28	0.23	0.19	0.16
OLS (Eq. 11)	E	0.83	0.69	0.57	0.47	0.39	0.32	0.27	0.22	0.18	0.15
Capitalized Tooling and Other Tools (6012)											
MLS (Eq. 27)	E	0.61	0.37	0.22	0.13	0.08	0.05	0.03	0.02	0.01	0.01
MLS (Eq. 25)	E	0.61	0.38	0.23	0.14	0.09	0.05	0.03	0.02	0.01	0.01
OLS (Eq. 11)	E	0.80	0.63	0.50	0.40	0.32	0.25	0.20	0.16	0.13	0.10
Drilling and Blasting Equipment (6013)											
MLS (Eq. 27)	E	0.80	0.65	0.52	0.42	0.34	0.27	0.22	0.17	0.14	0.11
MLS (Eq. 25)	E	0.81	0.66	0.54	0.44	0.35	0.29	0.23	0.19	0.15	0.13
OLS (Eq. 11)	W	0.93	0.81	0.68	0.56	0.44	0.34	0.26	0.19	0.14	0.10
Automobiles and Major Replacement Parts (6201)											
MLS (Eq. 27)	E	0.79	0.62	0.49	0.38	0.30	0.24	0.19	0.15	0.12	0.09
MLS (Eq. 25)	E	0.79	0.62	0.49	0.39	0.30	0.24	0.19	0.15	0.12	0.09
OLS (Eq. 11)	E	0.77	0.59	0.45	0.34	0.26	0.20	0.15	0.12	0.09	0.07
Buses (all types) and Other Field Equipment (6202)											
MLS (Eq. 27)	E	0.82	0.67	0.55	0.45	0.37	0.30	0.25	0.20	0.17	0.14
MLS (Eq. 25)	E	0.82	0.68	0.56	0.46	0.37	0.31	0.25	0.21	0.17	0.14
OLS (Eq. 11)	W	0.47	0.34	0.26	0.20	0.17	0.14	0.12	0.10	0.09	0.07
Trucks, Vans, Truck Tractors, Truck Trailers and Major Replacement Parts (6203)											
MLS (Eq. 27)	E	0.79	0.62	0.49	0.38	0.30	0.24	0.19	0.15	0.12	0.09
MLS (Eq. 25)	W	0.62	0.47	0.38	0.31	0.25	0.21	0.18	0.15	0.13	0.12
OLS (Eq. 11)	E	0.82	0.67	0.55	0.45	0.37	0.30	0.25	0.21	0.17	0.14
Locomotives, Rolling Stock, Street and Subway Cars, Other Rapid Transit and Major Parts (6205)											
MLS (Eq. 27)	E	0.85	0.72	0.61	0.52	0.44	0.38	0.32	0.27	0.23	0.20
MLS (Eq. 25)	E	0.85	0.72	0.61	0.52	0.44	0.37	0.31	0.27	0.23	0.19
OLS (Eq. 11)	E	0.81	0.65	0.53	0.43	0.35	0.28	0.23	0.18	0.15	0.12

Table 2.2 Ratio of the Residual Value: Machinery and Equipment – *Concluded*

		Age of Assets									
Asset	Model	1yr	2yr	3yr	4yr	5yr	6yr	7yr	8yr	9yr	10yr
Ships and Boats and Major Replacement Parts (6206)											
MLS (Eq. 27)	E	0.90	0.80	0.72	0.64	0.58	0.52	0.46	0.42	0.37	0.33
MLS (Eq. 25)	E	0.90	0.80	0.72	0.64	0.58	0.52	0.46	0.41	0.37	0.33
OLS (Eq. 11)	E	0.87	0.76	0.67	0.58	0.51	0.44	0.39	0.34	0.29	0.26
Aircraft, Helicopters, Aircraft Engines and Other Major Replacement Parts (6207)											
MLS (Eq. 27)	W	1.00	1.00	0.99	0.97	0.95	0.93	0.90	0.86	0.81	0.76
MLS (Eq. 25)	E	0.95	0.89	0.84	0.80	0.75	0.71	0.67	0.64	0.60	0.57
OLS (Eq. 11)	E	0.92	0.85	0.79	0.73	0.67	0.62	0.58	0.53	0.49	0.46
Other Transportation Equipment (6299)											
MLS (Eq. 27)	W	0.35	0.24	0.18	0.15	0.12	0.10	0.09	0.08	0.07	0.06
MLS (Eq. 25)	W	0.19	0.14	0.12	0.10	0.09	0.08	0.08	0.07	0.07	0.06
OLS (Eq. 11)	E	0.77	0.60	0.46	0.36	0.28	0.21	0.17	0.13	0.10	0.08
Computer-assisted Process for Production Process (6402)											
MLS (Eq. 27)	W	0.62	0.45	0.34	0.26	0.21	0.17	0.13	0.11	0.09	0.07
MLS (Eq. 25)	W	0.55	0.40	0.30	0.24	0.19	0.16	0.13	0.11	0.09	0.08
OLS (Eq. 11)	W	0.88	0.73	0.58	0.44	0.33	0.24	0.18	0.12	0.09	0.06
Computer-assisted Process for Communication and Related Equipment (6403)											
MLS (Eq. 27)	E	0.72	0.52	0.38	0.27	0.20	0.14	0.10	0.08	0.05	0.04
MLS (Eq. 25)	E	0.73	0.53	0.39	0.29	0.21	0.15	0.11	0.08	0.06	0.04
OLS (Eq. 11)	W	0.92	0.76	0.57	0.40	0.25	0.15	0.08	0.04	0.02	0.01
Non-computer Assisted Process for Material Handling (6601)											
MLS (Eq. 27)	W	0.55	0.40	0.31	0.25	0.20	0.16	0.14	0.11	0.10	0.08
MLS (Eq. 25)	W	0.26	0.19	0.15	0.12	0.11	0.09	0.08	0.07	0.07	0.06
OLS (Eq. 11)	E	0.82	0.68	0.56	0.46	0.38	0.31	0.25	0.21	0.17	0.14
Non-computer Assisted Process for Production Process (6602)											
MLS (Eq. 27)	W	0.60	0.43	0.33	0.26	0.20	0.16	0.13	0.11	0.09	0.08
MLS (Eq. 25)	W	0.48	0.34	0.26	0.20	0.16	0.14	0.11	0.09	0.08	0.07
OLS (Eq. 11)	E	0.83	0.68	0.56	0.46	0.38	0.32	0.26	0.22	0.18	0.15
Non-computer Assisted Process for Communication and Related Equipment (6603)											
MLS (Eq. 27)	W	0.38	0.20	0.12	0.07	0.05	0.03	0.02	0.01	0.01	0.01
MLS (Eq. 25)	E	0.58	0.33	0.19	0.11	0.06	0.04	0.02	0.01	0.01	0.00
OLS (Eq. 11)	W	0.88	0.70	0.53	0.39	0.27	0.18	0.12	0.08	0.05	0.03
Other Machinery and Equipment (8999)											
MLS (Eq. 27)	W	0.60	0.47	0.39	0.33	0.28	0.25	0.22	0.19	0.17	0.15
MLS (Eq. 25)	W	0.55	0.43	0.36	0.31	0.27	0.24	0.21	0.19	0.17	0.16
OLS (Eq. 11)	E	0.83	0.69	0.57	0.48	0.40	0.33	0.27	0.23	0.19	0.16

Table 2.3 Ratio of the Residual Value: Structures

		Age of Assets								
Asset	Model	1yr	2yr	3yr	4yr	5yr	10yr	15yr	20yr	25yr
Plants for Manufacturing (1001)										
MLS (Eq. 27)	W	0.77	0.65	0.56	0.49	0.43	0.25	0.15	0.10	0.07
MLS (Eq. 25)	W	0.67	0.54	0.46	0.40	0.35	0.21	0.14	0.10	0.07
OLS (Eq.11)	W	0.96	0.89	0.82	0.74	0.66	0.33	0.14	0.05	0.02
Warehouses, Refrigerated Storage, Freight Terminals (1006)										
MLS (Eq. 27)	E	0.94	0.88	0.83	0.78	0.73	0.54	0.39	0.29	0.21
MLS (Eq. 25)	E	0.94	0.88	0.83	0.78	0.74	0.54	0.40	0.29	0.22
OLS (Eq. 11)	W	0.95	0.88	0.81	0.73	0.65	0.34	0.16	0.07	0.03
Maintenance Garages, Workshops, Equipment Storage Facilities (1008)										
MLS (Eq. 27)	E	0.87	0.76	0.67	0.58	0.51	0.26	0.13	0.07	0.03
MLS (Eq. 25)	E	0.88	0.77	0.67	0.59	0.51	0.26	0.14	0.07	0.04
OLS (Eq. 11)	E	0.77	0.59	0.46	0.35	0.27	0.07	0.02	0.01	0.00
Office Buildings (1013)										
MLS (Eq. 27)	E	0.93	0.86	0.80	0.74	0.68	0.47	0.32	0.22	0.15
MLS (Eq. 25)	E	0.93	0.86	0.80	0.74	0.69	0.47	0.32	0.22	0.15
OLS (Eq. 11)	W	0.96	0.91	0.85	0.79	0.72	0.44	0.25	0.13	0.07
Shopping Centers, Plazas, Malls, Stores (1016)										
MLS (Eq. 27)	E	0.95	0.90	0.86	0.81	0.77	0.60	0.46	0.36	0.28
MLS (Eq. 25)	W	0.87	0.81	0.76	0.72	0.69	0.56	0.48	0.41	0.36
OLS (Eq. 11)	E	0.92	0.84	0.77	0.70	0.64	0.41	0.27	0.17	0.11
Other Industrial and Commercial (1099)										
MLS (Eq. 27)	E	0.93	0.86	0.79	0.73	0.68	0.46	0.31	0.21	0.14
MLS (Eq. 25)	E	0.93	0.86	0.80	0.74	0.68	0.47	0.32	0.22	0.15
OLS (Eq. 11)	E	0.89	0.79	0.70	0.63	0.56	0.31	0.17	0.10	0.05
Telephone and Cablevision Lines, Underground and Marine Cables (3002)										
MLS (Eq. 27)	E	0.68	0.47	0.32	0.22	0.15	0.02	0.00	0.00	0.00
MLS (Eq. 25)	E	0.76	0.58	0.44	0.34	0.26	0.07	0.02	0.00	0.00
OLS (Eq. 11)	W	0.93	0.81	0.67	0.54	0.41	0.07	0.01	0.00	0.00
Communication Towers, Antennae, Earth Stations (3003)										
MLS (Eq. 27)	W	0.98	0.93	0.86	0.78	0.69	0.28	0.07	0.01	0.00
MLS (Eq. 25)	E	0.87	0.76	0.67	0.58	0.51	0.26	0.13	0.07	0.03
OLS (Eq. 11)	E	0.73	0.53	0.38	0.28	0.20	0.04	0.01	0.00	0.00

model (equation 11) represents a comparatively simple (linear) formulation based strictly on the vector of average prices (where each price represents an average survival ratio given by equation 15). We have no strong priors as to whether this OLS specification will yield substantially different depreciation profiles than the more complex non-linear formulations represented by equations 25 and 27. Both our "final" rounding-corrected specification (equation 27) and our "intermediate" uncorrected specification (equation 25) are reported here in order to quantify the significance of digit preference (i.e., age-rounding) in our micro data. We discuss results for machinery and equipment and structures in turn.

Many assets in the machinery and equipment class exhibit substantial reductions in asset value early in service life (Table 2.2). To see this, consider the results of our rounding-corrected ML model (equation 27). Sixty-percent of the machinery and equipment assets studied (15 of 25) surpass their median survival value—the point at which one-half of total economic value is lost—prior to their 4th year of service life. Only 2 asset categories (ships and boats and aircraft) retain 50% of their value after 5 years. Assets for which large numbers of observations exist—e.g., computers (2,484), office furniture (2,651) and automobiles (2,554)—exhibit accelerated depreciation profiles. For computers, only a small residual of total value (6%) remains after the 5th year of operation.

In the main, large reductions in economic value for machinery and equipment assets accord with our expectations. For certain assets in this class, (e.g.) automobiles and computers, there is much evidence to suggest that the onset of economic depreciation is rapid.

High levels of depreciation are not unique to assets in the machinery and equipment class. Several of the assets in the structures class (Table 2.3) also exhibit this pattern. Plants for manufacturing—the asset category with the largest number of observations in this class—exhibit a highly accelerated depreciation profile. According to our rounding-corrected model (equation 27), only 43% of the total plant value remains after the 5th year of operation, and only one-quarter of total value survives the first decade of service life. While other large-sample assets (e.g., warehouses and office buildings) exhibit less precipitous reductions in asset value, there is evidence that the overall magnitude of economic depreciation is nonetheless substantial. To see this, we can focus on estimated survival rates after a decade of service life. Warehouses retain slightly more than their median survival value (the point at which one-half of total value is exhausted), while office buildings eclipse their median survival value by their tenth year of operation.

High levels of depreciation among structures are not, in our view, counterintuitive. On this, the case of plants is illustrative. First, there is anecdotal evidence that plant depreciation is relatively high due to changes in technology. Second, many of their production characteristics are idiosyncratic. In many situations, the production characteristics of a plant are not readily transferable from existing owners to new owners, that is, from current-use to future-use. If prospective owners expect to incur high retooling and refitting costs, the current market value of the plant (based, in part, on what the new owner is willing to pay) may be substantially diminished. These situations reinforce the price concept being evaluated herein: estimates of depreciation are based on market prices, observed as assets are transferred from owner-to-owner, and not on reservation prices, which identify the value of the asset to its current owner (i.e., in its current productive use).

While many of our results suggest that the magnitude of economic depreciation is substantial, evidence on whether rates of depreciation are age-invariant or variable over the course of service life is, on balance, mixed. To see this, we again focus on our final, rounding-corrected, ML specification (equation 27). Statistical grounds for rejecting the null of an age-invariant rate were apparent for only 2 of 8 structures and 12 of the 25 machinery and equipment assets considered herein.

We have based our discussion of results on what, in our view, represents the (theoretically) optimal estimation vehicle—the rounding-corrected model described by equation 27. However, differences in estimated profiles within an asset class can occasionally be striking (e.g., see results for plants (1001) and towers (3003) in the structures class, along with office furniture (6001) and non-computer assisted process for production (6602) in the machinery and equipment class).

We expect to observe differences between our OLS average-price and MLS formulations because the methodological underpinnings of each are quite distinct. As outlined in Section 2.4, the average-price model is a simple linear transformation of the Weibull survivor function, and is estimated from weighted survival ratios. By contrast, the ML model is based on an explicit survival formulation that fully integrates all micro-information from the asset samples. In many cases, the linear model yields substantially higher SFEs than the MLS model (e.g., computer and non-computers assisted processes and motors). In a more limited number of cases, the linear model generates higher levels of depreciation (e.g., pollution abatement equipment and buses).

Comparisons between the two ML formulations are of a more direct nature—as they simply quantify the bias of age-rounding. For the majority of assets in our sample, the rounding-corrected and uncorrected ML models yield very similar results (e.g., heavy construction equipment and capitalized tooling equipment), or unearth only qualitatively modest differences (e.g., heating equipment). In some cases, however, the impact of age bias on the depreciation estimates is substantial—typically bringing about more acceleration in the uncorrected depreciation profile (e.g. office furniture, motors and trucks). Higher survival rates in the presence of digit preference are less common (e.g., non-computer assisted processes for communications and telephone lines).

2.5.2 Econometric versus Non-econometric Results: Select Assets

For many of the assets studied, our ML survival model generates accelerated depreciation profiles. All comparisons to this point, however, have been based on alternative formulations of our econometric framework. In this section, we compare two of these econometric results—the OLS average price model (equation 11) and the rounding-corrected ML model (equation 27)—to two non-econometric profiles, first, an actual age-price profile represented by the vector of observed prices at different ages $\bar{R}(t)$, and second, a geometric profile based on the *ex ante* accounting method described by equation 4. The first of these non-econometric approaches, the age-price profile, is the locus of average survival ratios, each of which constitutes an independent point-estimate at some corresponding age. This profile, then, does not represent a survival curve, in the sense that there is no mathematical relationship between subsequent point estimates (a mathematical property of survival curves).

By contrast, the second of these non-econometric approaches, the geometric profile, does represent a survival curve that is directly comparable to our econometric estimates. To calculate this profile from equation 4, we calculate rates of depreciation by

Figure 2.3 Comparative Depreciation Profiles: Computers, Associated Hardware and Word Processors

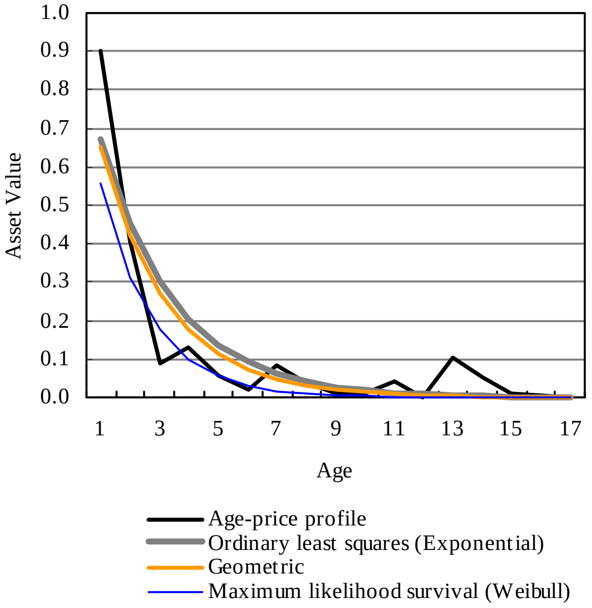
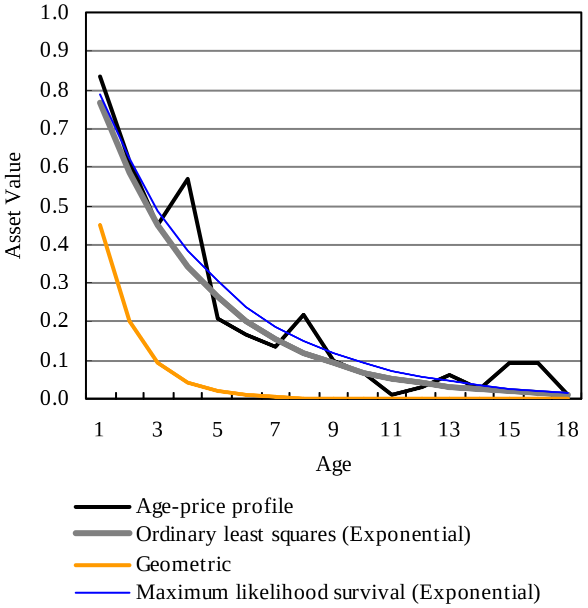


Figure 2.4 Comparative Depreciation Profiles: Automobiles and Major Replacement Parts



assuming BEA-style values for the declining-balance rate (*DBR*=1.65 for machinery and equipment and 0.91 for structures) and obtaining asset-specific estimates of mean service life from the Capital and Repair Expenditures Survey.[23] We then used the indirect rate of depreciation, calculated from equation 4, to plot the subsequent profile.

We present these results graphically for two machinery and equipment assets, computers and automobiles, and one asset in the structures class, plants for manufacturing.

Comparative depreciation profiles for computers are examined in Figure 2.3. The vector of reported survival ratios $\bar{R}(t1),\ldots,\bar{R}(n)$ that traces out the age-price profile is represented by the heavy solid line. This non-econometric age-price plot provides some initial evidence of large declines in asset value during early stages of service life. Our OLS average-price model (equation 11) is estimated directly from this age-price plot and generates depreciation estimates that are very similar to our *ex ante* geometric accounting method (equation 4). Our rounding-corrected maximum-likelihood model (equation 27) produces a depreciation profile with higher reductions in asset value early in service life. This maximum likelihood formulation provides evidence of a variable depreciation rate, while the OLS model supports the null of a constant rate.

Depreciation estimates for automobiles are examined in Figure 2.4. Once again, the reported age-price profile indicates that large reductions in asset value occur early in service life. In this case, both econometric techniques produce very similar profiles—which closely track average prices. The OLS and ML survival models also provide evidence of a constant, age-invariant depreciation rate. While the *ex ante* geometric method also (by design) generates a constant rate, it yields very different depreciation

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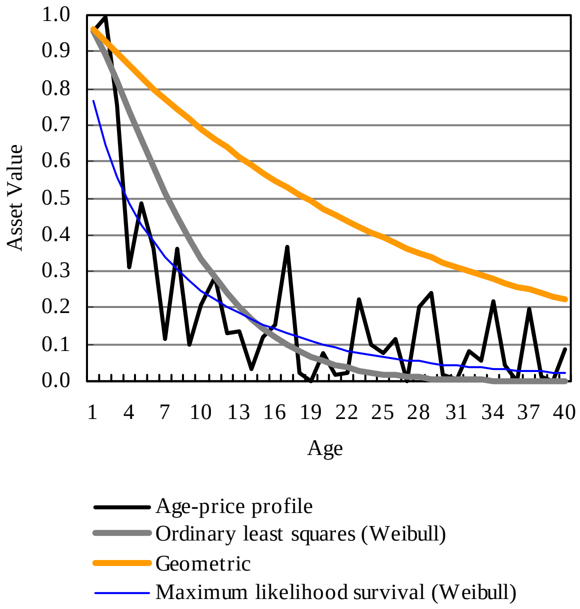
[23] Data on service lives was obtained for the period 1995-1997. Mean service lives are investment-weighted.

Figure 2.5 Comparative Depreciation Profiles: Manufacturing Plants



estimates than either of our econometric techniques. These rapid declines in asset value come about because of low estimates of service life (an average of 3.0 years).

For plants, the age-price plot traced out by the average survival ratios $\bar{R}(t1),...,\bar{R}(n)$ is comparatively volatile—with substantial fluctuations in asset value at mid-to-late stages of service life (Figure 2.5). The OLS-based depreciation profile generated directly from these average price ratios produces a highly-accelerated pattern with steep declines in asset value. Rates of depreciation from the OLS model are variable at different stages of the lifecycle. The OLS profile reaches its asymptote (with virtually all survival value exhausted) at a service life of about 25 years. The depreciation profile generated by our ML survival model is also accelerated—but with more rapid declines in asset value early in service life. While this profile also declines at a variable rate, reductions in value during mid-to-late stages of the lifecycle are more modest than in the OLS case. Our non-econometric geometric profile—based on BEA-style values for the declining-balance rate and recent data on service life—again differs substantially from our econometric results. This *ex ante* geometric technique produces a low depreciation rate (and correspondingly high survival function estimates), due to a combination of a low *DBR* (0.91) and a long estimated service life (24.7 years).

The above results are based on survival curves—a locus of probability estimates that track changes in asset value at various stages of service life. One advantage of the parametric distributions utilized herein (i.e., Weibull, exponential and geometric) is that all allow for the straightforward derivation of summary measures that can be used to compare the various depreciation profiles. We examine one such measure below.

2.5.3 Mean Value-life

To compare differences in depreciation profiles, we calculate the asset's *mean value life*—a simple measure of central tendency, expressed in years, that reflects observed changes in valuation at all stages of an asset's lifecycle. For our econometric estimates of depreciation, mean value-life is just the estimated mean of the survival distribution. When depreciation profiles are based on the Weibull, or age-variant, version of our model, this mean value-life is

$$MVL = \frac{1}{\lambda}\Gamma[(\rho+1)/\rho]. \tag{28}$$

For the exponential (restricted) version of our model, the mean is

$$MVL = \frac{1}{\lambda}. \qquad (29)$$

A comparable measure of central tendency can also be derived from our non-econometric accounting framework. Recall the rate of geometric depreciation from equation 4 is just

$$\delta = \frac{DBR}{L} \qquad (30)$$

which determines the curvature of the subsequent depreciation profile. The mean of the geometric profile is just the inverse of the rate,

$$\mu = \frac{1}{\delta} \qquad (31)$$

or equivalently,

$$\mu = \frac{L}{DBR}. \qquad (32)$$

Equation 32 is illuminating because it indicates how relationships between economic value and physical service life are affected by the declining balance rate. If the *DBR* equals unity, mean value-life is equal to service life. Similar, for values of *DBR* greater than unity, the mean value-life (conceptually a measure of central tendency) is less than estimated service life. Equation 32 thus provides us with a price, or value, based concept from the geometric accounting framework that is comparable to equations 28 and 29.

We examine differences in mean value-life in tables 2.4 and 2.5. Once again, we report estimates from our two econometric techniques—the OLS and MLS models described by equations 11 and 27—along with non-econometric results based on equation 32. Here, we offer two non-econometric estimates of mean life—first, using the more traditional double-declining balance rate, and second, using BEA-style values for the declining balance rate (which were used to derive the geometric profiles in Section 2.5.2).

We observed earlier that our ML survival model (equation 27) often generates high rates of economic depreciation. We can assess this further by comparing summary statistics from this model with those derived from the double-declining geometric method—the version of our *ex ante* formulation (equation 32) that generates the highest levels of depreciation—and testing for differences. For a slight majority of machinery and equipment assets (14 of 25), the mean-value life estimates generated from the ML survival model are significantly shorter than those generated via the double-declining balance method (Table 2.4). Conversely, there are only 4 machinery and equipment assets for which our rounding-corrected ML survival formulation produces significantly longer summary measures than the double-declining method.

Table 2.4 Mean Value-life in Years: Machinery and Equipment (Confidence Intervals in Parentheses)

	OLS	MLS	Geometric DBR=2	Geometric DBR=1.65
Office Furniture, Furnishings (6001)	4.7 (3.3, 6.1)	3.3 (3.2, 3.5)	3.0 (3.0, 3.1)	3.7 (3.6, 3.7)
Computers, Associated Hardware and Word Processors (6002)	2.5 (1.3, 3.7)	1.7 (1.7, 1.8)	2.3 (2.3, 2.4)	2.8 (2.8, 2.9)
Non-office Furniture, Furnishings and Fixtures (6003)	4.8 (3.1, 6.6)	4.7 (4.5, 5.0)	4.0 (3.9, 4.1)	4.8 (4.7, 4.9)
Scientific, Professional and Medical Devices (6004)	5.3 (3.9, 6.6)	3.9 (3.8, 4.1)	5.1 (5.0, 5.3)	6.2 (6.0, 6.5)
Heating, Electrical, Plumbing, Air Conditioning and Refrigeration Equipment (6005)	4.4 (3.4, 5.4)	3.7 (3.4, 4.1)	6.4 (6.2, 6.6)	7.8 (7.5, 8.0)
Pollution Abatement and Control Equipment (6006)	1.9 (1.2, 2.7)	4.5 (3.7, 5.2)	8.8 (8.5, 9.1)	10.7 (10.4, 11.0)
Safety and Security Equipment (6007)	1.8 (1.1, 2.5)	2.2 (1.8, 2.6)	5.1 (4.9, 5.4)	6.2 (5.9, 6.5)
Motors, Generators, Transformers, Turbines, Compressors and Pumps of all types (6009)	7.2 (5.7, 8.8)	4.0 (3.6, 4.5)	11.9 (11.5, 12.3)	14.4 (13.9, 14.9)
Heavy Construction Equipment (6010)	5.5 (4.0, 7.0)	5.2 (4.8, 5.6)	3.6 (3.4, 3.9)	4.4 (4.1, 4.7)
Tractors and Other Field Equipment (6011)	5.3 (3.3, 7.3)	5.2 (4.7, 5.7)	6.6 (6.1, 7.2)	8.0 (7.4, 8.7)
Capitalized Tooling and Other Tools (6012)	4.4 (2.9, 5.9)	2.0 (1.8, 2.1)	3.4 (3.2, 3.5)	4.1 (3.9, 4.3)
Drilling and Blasting Equipment (6013)	5.1 (3.7, 6.6)	4.6 (3.8, 5.4)	5.8 (5.1, 6.6)	7.0 (6.2, 8.0)
Automobiles and Major Replacement Parts (6201)	3.8 (2.1, 5.4)	4.2 (4.0, 4.3)	1.5 (1.5, 1.5)	1.8 (1.8, 1.8)
Buses (all types) and Other Field Equipment (6202)	3.0 (0.5, 5.5)	5.0 (4.3, 5.7)	5.8 (5.1, 6.5)	7.0 (6.2, 7.9)
Trucks, Vans, Truck Tractors, Truck Trailers and Major Replacement Parts (6203)	5.1 (3.1, 7.0)	4.2 (4.0, 4.3)	2.8 (2.7, 2.8)	3.4 (3.3, 3.4)
Locomotives, Rolling Stock, Street and Subway Cars, Other Rapid Transit and Major Parts (6205)	4.7 (3.2, 6.2)	6.2 (5.3, 7.0)	10.1 (9.7, 10.5)	12.2 (11.8, 12.7)
Ships and Boats and Major Replacement Parts (6206)	7.4 (5.1, 9.6)	9.1 (7.3, 10.8)	8.1 (6.4, 10.1)	9.8 (7.8, 12.3)
Aircraft, Helicopters, Aircraft Engines and Other Major Replacement Parts (6207)	12.7 (7.3, 18.1)	15.0 (14.2, 15.9)	8.9 (8.6, 9.2)	10.8 (10.5, 11.1)
Other Transportation Equipment (6299)	3.9 (2.4, 5.4)	2.5 (1.6, 3.5)	3.5 (3.2, 3.8)	4.2 (3.9, 4.6)
Computer-assisted Process for Production Process (6402)	4.3 (3.2, 5.3)	3.3 (2.9, 3.6)	5.7 (5.5, 5.9)	6.9 (6.7, 7.1)
Computer-assisted Process for Communication and Related Equipment (6403)	3.7 (2.8, 4.7)	3.1 (2.7, 3.5)	5.4 (5.2, 5.6)	6.5 (6.4, 6.7)
Non-computer Assisted Process for Material Handling (6601)	5.1 (3.3, 6.9)	3.3 (3.0, 3.7)	5.0 (4.9, 5.2)	6.1 (5.9, 6.3)
Non-computer Assisted Process for Production Process (6602)	5.2 (3.7, 6.8)	3.3 (3.1, 3.4)	6.6 (6.5, 6.7)	8.0 (7.8, 8.1)
Non-computer Assisted Process for Communication and Related Equipment (6603)	3.8 (2.8, 4.7)	1.3 (1.1, 1.4)	4.4 (4.2, 4.5)	5.3 (5.1, 5.5)
Other Machinery and Equipment (8999)	5.4 (3.6, 7.3)	5.4 (4.7, 6.1)	4.4 (4.1, 4.7)	5.3 (5.0, 5.7)

Table 2.5 Mean Value-life in Years: Structures (Confidence Intervals in Parentheses)

	OLS	MLS	Geometric DBR=2	Geometric DBR=0.91
Plants for Manufacturing (1001)	8.5 (6.9, 10.1)	7.7 (7.0, 8.5)	12.3 (12.0, 12.7)	27.1 (26.5, 27.8)
Warehouses, Refrigerated Storage, Freight Terminals (1006)	8.7 (6.9, 10.5)	16.1 (14.1, 18.0)	12.7 (12.2, 13.3)	28.0 (26.8, 29.1)
Maintenance Garages, Workshops, Equipment Storage Facilities (1008)	3.8 (2.6, 5.1)	7.4 (6.3, 8.6)	13.1 (12.6, 13.7)	28.9 (27.7, 30.1)
Office Buildings (1013)	10.8 (8.5, 13.1)	13.2 (12.2, 14.2)	12.7 (12.3, 13.1)	27.9 (27.1, 28.8)
Shopping Centers, Plazas, Malls, Stores (1016)	11.4 (7.0, 15.7)	19.4 (16.7, 22.1)	13.3 (12.6, 14.0)	29.1 (27.6, 30.8)
Other Industrial and Commercial (1099)	8.6 (6.0, 11.2)	12.9 (11.0, 14.9)	12.3 (11.6, 13.1)	27.1 (25.4, 28.9)
Telephone and Cablevision Lines, Underground and Marine Cables (3002)	4.8 (3.7, 6.0)	2.6 (2.2, 3.0)	9.2 (8.6, 9.7)	20.1 (18.9, 21.4)
Communication Towers, Antennae, Earth Stations (3003)	3.1 (2.0, 4.3)	7.8 (7.0, 8.5)	6.5 (6.2, 6.7)	14.2 (13.6, 14.8)

For one-half of the structures evaluated herein (4 of 8), mean-value lives from the ML survival model are significantly shorter than those generated via the double-declining method (Table 2.5). In 2 of 8 cases (office buildings and other industrial structures) differences in these summary measures are not quantitatively meaningful. In two other cases (warehouses, shopping centers), our ML survival model generates significantly longer estimates of economic life than the double-declining method. However, *both* the econometric and double-declining estimates of mean-value life are much lower than those generated via the geometric approach when BEA-style assumptions about the *DBR* are used in place of the double-declining rate of two.[24] In all cases, this BEA-style geometric method produces much lower rates of depreciation.

In what follows, we place comparisons between our MLS technique and these *ex ante* methods in a larger context—by evaluating their impact on the estimation of capital stock.

2.6 Capital Stock

2.6.1 Perpetual Inventory Estimates of Capital Stock

In this section, we generate estimates of capital stock based on our rounding-corrected ML survival model, and compare these to two different stock estimates based on *ex ante* depreciation methods (represented by equation 4). Estimates of capital stock are based on the perpetual inventory model

$$K(t) = I(t) + (1-\delta)K(t-1) \qquad (33)$$

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[24] Note from equation 32 that an asset's mean-value life μ —generated from the geometric depreciation profile—is longer than service life L when adopting a BEA-style *DBR* of 0.91 for structures.

where δ represents a (constant) geometric rate of depreciation that proxies the rate of replacement.

To produce econometric estimates of δ ,we estimated the restricted (exponential) form of our rounding-corrected model (equation 27) for 59 individual assets and 5 asset combinations[25], and then used the estimated depreciation rates from this model to construct aggregate summary rates of depreciation for 19 different Hicksian asset groups—6 asset groups for structures and 13 asset groups for machinery and equipment.[26] These 19 asset groups were derived using historical information on service life.

We report depreciation rates for these asset groups in Appendix 2.C.

In what follows, we report two sets of estimates from our maximum-likelihood survival model. The first estimate is based on the full sample of individual prices, employing all useable information on selling prices and discards. The second estimate is based on a reduced sample of observations in which (i) a subset of zero prices (i.e., discards) has been eliminated and (ii) select adjustments have been made to different asset-specific depreciation rates. This second approach was used to generate depreciation rates for Statistics Canada's most recent set of multifactor productivity estimates. We discuss these adjustments in more detail in Appendix 2.C.

We also generate stock estimates using depreciation rates from *ex ante* geometric accounting techniques. As in Section 2.5, we based these rates of depreciation on estimates of mean service life from Statistics Canada's *Capital and Repair Expenditures Survey*. Investment-weighted service lives were calculated over the 1995-1997 period for each of the asset categories required for the perpetual inventory calculation. Two different sets of depreciation estimates were then generated using different assumptions about the declining balance rate. First, we assumed a traditional double-declining rate of 2 for both machinery and equipment and structures. Second, we used BEA-style values of 1.65 for machinery and equipment assets and 0.91 for structures.

We present our stock estimates in Figure 2.6. Note that these estimates are generated strictly for expositional purposes.

The *ex ante* BEA-style depreciation estimates produce the largest stock estimates over the 1961-1996 period, followed by the *ex ante* double-declining approach. The exponential rates of depreciation generated by our econometric model generate the lowest stock levels over this period—using either the reduced sample (see Appendix 2.C) or all information on discards. We assess the level of precision inherent in our econometric technique by calculating 5% confidence intervals around the stock estimates. We present these graphically around the reduced-sample stock estimate in Figure 2.6. These upper and lower-bounds are virtually identical to the corresponding estimate. Hence, our MLS estimation framework yields very precise estimates of capital stock.

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[25] In certain cases, we estimated econometric rates of depreciation for various asset combinations in order to overcome sample limitations. Five such combinations were estimated, containing price information on 52 individual assets.

[26] Because our principal objective at this stage was to produce depreciation rates for aggregate asset groupings, we were able to use more information on individual assets from our database. To produce summary rates of depreciation for the 19 asset groups, we utilized over 27,300 observations on 111 individual assets. For assets with large numbers of observations, we also estimated rates of depreciation for different industry groupings.

Figure 2.6 Comparative Estimates of Capital Stock (1992 Prices)

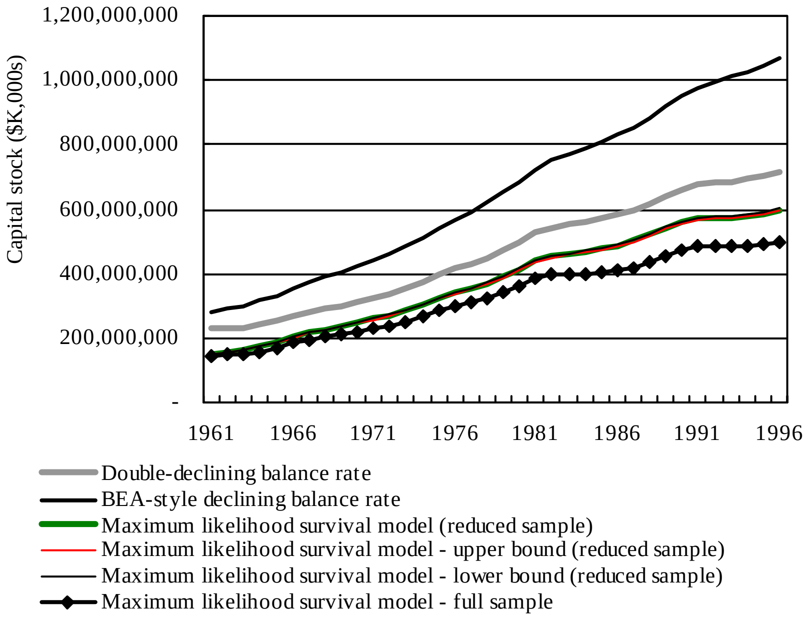


Figure 2.7 Normalized Stock Estimates

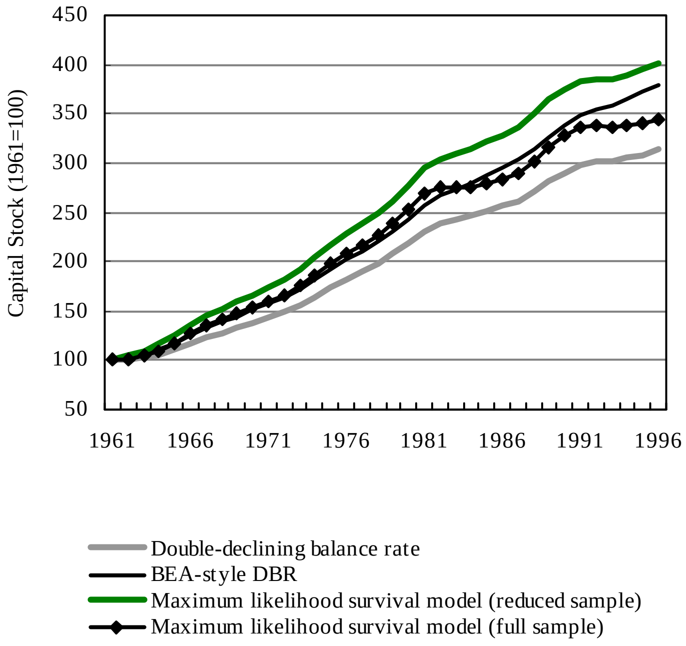


Table 2.6 Comparative Growth Rates in Real Capital Stock Under Alternative Depreciation Regimes (%)

	BEA-style DBR	**DDBR**	**MLS Model** (full sample)	**MLS Model** (reduced sample)
Growth Rate (1961-1995)	3.89	3.32	3.60	4.05
Structures	4.53	4.12	4.78	5.06
Machinery and Equipment	3.73	3.07	3.10	3.63

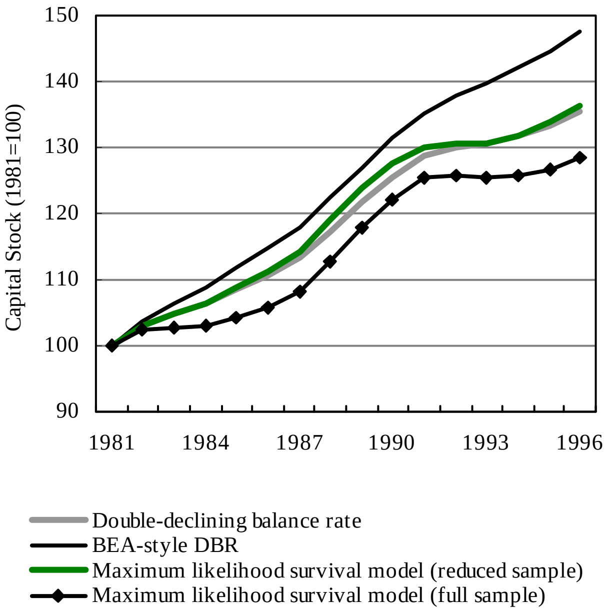
We now turn to consider patterns of capital growth. Multifactor productivity estimates, key performance indicators, are based on rates of growth in factor inputs, not on the value, or level, of inputs in any one period. Differences in levels of capital stock depicted in Figure 2.6 may obscure differences in patterns of capital growth—because each estimate assumes a different starting level in 1961. To compare the impact of our depreciation techniques on the growth of capital stock, we first normalized each stock estimate to a value of 100 in 1961. The resulting growth profiles are presented in Figure 2.7 and Table 2.6.

The *ex ante* double-declining approach generates the lowest growth path over the 1961-1996 period, with an annual growth rate of 3.3% By comparison, growth rates using the ML survival (full sample) and BEA-style depreciation techniques are 3.6% and 3.9%, respectively. These latter two depreciation techniques generate faster, and quite similar, growth trends over the pre-1980 period. After 1980, however, depreciation estimates from the ML survival model (full sample) produce growth patterns that are more comparable to those generated via the double-declining method. The growth in capital stock slows during the early-to-mid 1980s, and then again after 1991—trends that are particularly apparent in our econometric-based estimates. This apparent decline in stock growth coincides with years in which gross investment ratios—investment expressed as a percentage of GDP—are also in relative decline (Baldwin et al., 2001). These post-1980 slowdowns are not apparent when using the BEA-style depreciation estimates—as the evolution of capital stock largely mirrors its pre-1980 trend. The growth profile from the ML survival model (reduced sample) also mirrors the trend generated via double-declining depreciation. This estimation approach yields a higher rate of capital growth (4.1%) than any of the other depreciation estimates presented herein.

The results of the above exercise suggest that our *ex post* survival model gives rise to higher capital stock growth rates—at least when compared to the more traditional double-declining method of depreciation. While the econometric estimates of depreciation for individual assets in our sample often generate accelerated declines in asset value, these do not bring about precipitous reductions in capital growth when our technique is integrated into the perpetual inventory framework. The relationship between asset-specific rates of depreciation and the overall stock estimates is not straightforward; it depends how the individual asset classes are aggregated, and, in turn, how these aggregate groupings are weighted when generating the capital stock estimate.

It should be stressed, however, that the above conclusions about relative long-run growth paths are contingent upon the year at which stock levels are normalized. We have selected 1961 as our start point for these capital stock exercises as our interest lies, initially, in characterizing long-run trends. If we select another, more current, year as our basis for normalization—for instance, 1981—different conclusions may emerge. We examine these alternative growth paths based on 1981 normalization in Figure 2.8.

Figure 2.8 Normalized Stock Estimates



In this more recent period, the alternative depreciation techniques generate a different set of impressions regarding the growth of capital stock. BEA-style depreciation rates give rise to a significantly higher rate of capital growth (an average annual rate of 2.6%) than other depreciation methods. The depreciation estimates from our MLS survival model (reduced sample) generate a growth profile over this more recent period that is very similar to that generated via the *ex ante* double-declining estimates (both yield a growth rate of 2.1%). The MLS estimates based on full price samples generate the lowest growth rate at 1.7%.

2.7 Conclusion

In this chapter, we use Weibull survival models to estimate patterns of economic depreciation based on rich samples of used-asset prices and discards. Three variants of our estimation framework were proposed: a simple linear model estimated via average prices, and two-maximum likelihood models that generate depreciation estimates directly from samples of micro-data. Our second maximum likelihood formulation adjusts for patterns of digit preference.

The depreciation profiles generated by our econometric techniques are, on balance, accelerated, producing convex age-price curves. Substantial reductions in economic value are apparent early in life for many assets in the machinery and equipment class, as well as for certain structures. Evidence that rates of depreciation are constant over service life is, on balance, mixed.

Differences in the econometric formulation of our Weibull survival model can give rise to discordant impressions of how rapidly asset values erode over the course of service life. In our view, the rounding-corrected maximum likelihood specification should be viewed as the optimal estimation vehicle—as it makes full use of sample information *and* accounts for patterns of age-rounding in the price data. Comparisons between our MLS model and *ex ante* geometric approaches reveal, first, that our econometric techniques generate comparably high levels of depreciation, and second, that *ex ante* rates are particularly sensitive to the choice of declining-balance rate.

We then compared our econometric approach to *ex ante* geometric methods by generating different estimates of capital stock. To do so, we estimated a restricted (exponential) version of our rounding-corrected survival model and produced aggregate depreciation rates for different asset classes. We generated two capital stock estimates from our econometric approach—the first using all useable information on prices and discards and the second using more restricted data samples that eliminate potentially spurious information on discards. This latter approach also included several adjustments to our econometric depreciation rates.

We then calculated geometric *ex ante* rates of depreciation for our asset classes, using different assumptions about the declining balance rate, and compared the subsequent stock estimates. When capital stock levels are examined over the 1961-1996 period, our econometric approach generates lower stock estimates than those generated by *ex ante* geometric techniques. When levels are normalized to examine differences in secular growth rates over this period, our econometric approach yields higher rates of capital growth than that generated via double-declining geometric depreciation.

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Appendix 2.A: Outlier Identification and Edit Strategy

In preparing our asset samples for estimation, we identified subsets of records that, relative to the majority of observations in their asset categories, exhibited either highly undervalued resale prices in early stages of service life, or highly overvalued resale prices at late stages. As noted in Section 2.3, we removed these outlier observations from our asset samples. In principle, we could identify outliers on an asset-by-asset basis via visual examinations of age-survival plots. However, this entails a high degree of subjective judgement, and may give rise to inconsistencies in the treatment of certain types of observations across asset categories. Consequently, we based our method of identification on a set of systematic rules. These are described below.

First, we calculate minimum and maximum survival times for a given asset using information on discards—observations with a selling price of zero, but with information on gross book value and age. We begin by assuming that the retirement age of an asset (expressed in log form) follows a normal distribution. We represent this graphically in Figure 2.A1. The lower and upper bounds correspond to the youngest and oldest retirement ages at the 10% confidence level. Minimal survival time is defined at the lower bound, and maximum survival time is defined at the upper bound weighted by an adjustment factor of 1.2.[27]

All observations in areas A, B and C are removed from sample. Area A includes observations which have "unreasonably low" survival rates at an early age. This area is bounded by a quadratic frontier connecting point U (the "start" point[28]) and the minimum age M (i.e., the lower boundary below which zero sale prices are rejected). Area B includes observations which have "unreasonably high" survival rates well into their service life. This area is bounded by a linear frontier connecting point V (corresponding to a survival rate that equals one-half of maximum life) and point N (maximum life). Area C identifies all observations with survival rates greater than one (i.e., assets that appreciate in constant dollars).

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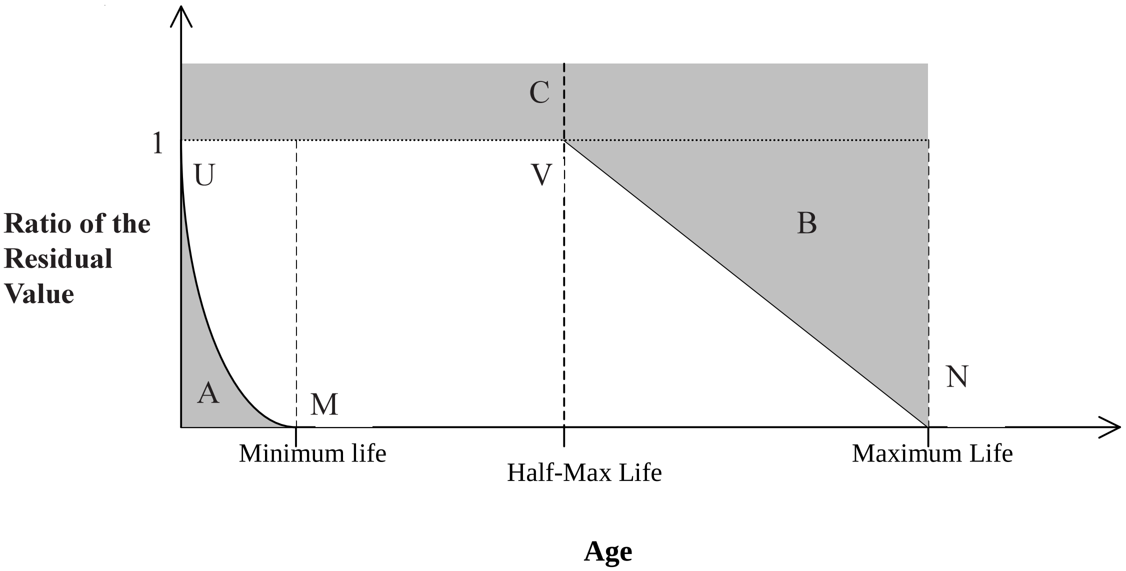
[27] This weighting adjustment was made in order to define roughly symmetrical rejection areas on both sides of the distribution.

[28] That is, the point corresponding to a zero age and a survival rate of unity.

Figure 2.A1: Outlier Identification



Appendix 2.B: Generalized Residuals, Specification and Heterogeneity Tests

Following Lancaster (1985a), we made use of generalized residuals to develop specification and heterogeneity tests.

Using the fact that integrated hazards are generalized errors and that their distribution is unit exponential, Lancaster used the moment generating functions $\varepsilon(t)$ and log $\varepsilon(t)$ to build specification tests for any distribution used in survival analysis. In the case of uncensored data, integrated hazards computed from maximum likelihood estimates provide the generalized residuals *e(t)*. Accordingly, for the Weibull distribution

$$f(t) = (\lambda t)^{\rho-1} \lambda\rho \exp(-\lambda t)^{\rho} \tag{B1}$$

The generalized residuals are computed as

$$e(t) = (\hat{\lambda} t_i)^{\hat{\rho}} \tag{B2}$$

where $\hat{\lambda}$ and $\hat{\rho}$ are ML estimators.

In the case of right censoring Lancaster (1985b)[29] derived the generalized residual from the ML estimates of the conditional mean of the generalized error. He used the expectation

$$E(\varepsilon(T)\,|\,T > s) \tag{B3}$$

where *T* denotes the random variable and *s* the censoring time.

Given *f*(t), the density function of $\varepsilon(t)$ (unit exponential) and Pr(*T*>*s*) the probability that *T* exceeds *s*, the conditional expectation becomes

---

[29] The formulation used by Lancaster for the Weibull distribution is slightly different from ours. In his case, the exponent ρ applies only to *t*, the time variable.

$$E(\varepsilon(T)\,|\,T>s)=\int_s^{\infty}\frac{\varepsilon(t)\,f(\varepsilon(t))}{\Pr(T>s)}= \tag{B4}$$

$$\int_s^{\infty}\frac{\varepsilon(t)\exp(-\varepsilon(t))}{\exp(-\varepsilon(s))}d\varepsilon(t)=\Bigg|_s^{+\infty}\frac{-\exp(-\varepsilon(t))-\varepsilon(t)\exp(-\varepsilon(t))}{\exp(-\varepsilon(s))}=1+\varepsilon(s)$$

Using the same approach, we now derive the generalized error in the case of left censoring. We have[30]

$$E(\varepsilon(T)\,|\,T<s)=\int_0^{s}\frac{\varepsilon(t)\,f(\varepsilon(t))}{\Pr(T<s)}=\int_0^{s}\frac{\varepsilon(t)\exp(-\varepsilon(t))}{1-\exp(-\varepsilon(s))}d\varepsilon(t)= \tag{B5}$$

$$\Bigg|_0^{s}\frac{-\exp(-\varepsilon(t))-\varepsilon(t)\exp(-\varepsilon(t))}{1-\exp(-\varepsilon(s))}=1-\frac{\varepsilon(s)\exp(-\varepsilon(s))}{1-\exp(-\varepsilon(s))}$$

from which generalized residuals are computed. Recall that our maximum likelihood function has the general form

$$L=\Sigma_i\, w_i\big[(1-R_i)\,F(t_i)-R_i\;S(t_i)\big] \tag{B6}$$

where R_i is the survival (price) ratio, w_i the constant dollar weight, and $F(t_i)$ and $S(t_i)$ represent the cumulative density and survivor functions, respectively. Because of the double-censoring specification, all observed times are treated as censoring times. The generalized residual becomes a mixture of equations B5 and B6. We have

$$\hat{e}=(1-R_i)\left\{1-\frac{\varepsilon(t_i)\exp(-\varepsilon(t_i))}{1-\exp(-\varepsilon(t_i))}\right\}+R_i(1+\varepsilon(t_i))\,. \tag{B7}$$

Using the ML estimators from the Weibull distribution, it can be shown that the weighted mean of the residuals equals unity. Following the methodology proposed by Tauchen (1985), and developed by Pagan and Vella (1989), Jaggia (1991a, 1991b) developed tests for specification and heterogeneity of duration models. The advantage of this methodology is that it takes into account the possible correlation between the tests. Given that the generalized residuals are unit exponential, their theoretical moments are known, and any combination of different moments can be used for the construction of a test.[31]

The test statistic that we used to evaluate heterogeneity and specification is

$$\chi^2{}_k=RW'M(M'M-M'D(D'D)^{-1}D'M)^{-1}M'RW \tag{B8}$$

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[30] We use the identity $\int xe^{-x}dx=-e^{-x}-xe^{-x}$.

[31] Kiefer (1985) proposed the use of Laguerre polynomials in a similar construction.

where k is the number of moments tested simultaneously and RW is a column vector of length n containing the square root of the weights. M is n x k matrix of the individual terms in the moment, while D is the empirical gradient of the maximum likelihood function. For M and D, individual elements are pre-multiplied by the square root of the weight so that the χ^2 statistics respect the weighting system.

Two joint tests were built in order to test for specification and heterogeneity. The nulls were always strongly rejected.

The implications of our heterogeneity and specification tests need to be set in context. Our rationale for specifying a Weibull-based survival model is that *a priori* it yields an analytically sensible characterization of the depreciation process—one that can easily be reconciled with standard geometric accounting methods. While our statistical tests do not provide evidence for the Weibull, it may be difficult to define a more appropriate *generalized* parametric framework, if asset-specific depreciation profiles are highly heterogeneous. We do not have strong priors that the adoption of an alternative, more sophisticated, parametric form would improve our results significantly. As Heckman and Singer (1984) note, one runs the risk of over-parameterizing the model without concomitant gains in explanation.

An alternative approach is to move away from a generalized parametric framework—in favour of defining different parametric models on an asset-to-asset basis. This, however, may complicate many of our analytics—and render comparability difficult. In addition, it would sever the conceptual linkage between our exponential (i.e., restricted Weibull) estimates of economic depreciation and the rates of replacement that are used to generate stock estimates via the perpetual inventory model.

These parametric issues aside, the presence of heterogeneity in our data samples does suggest that we should attempt to integrate additional information into our analysis of the depreciation process. The inclusion of macroeconomic, industry-level, and firm-specific covariates would strengthen the estimation framework.

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Appendix 2.C: Depreciation Inputs for Capital Stock Estimation

Our experimental estimates of capital stock are based on constant (age-invariant) rates of depreciation that correspond to different asset groupings. In all, summary rates of depreciation were generated for 19 different asset groups—13 for machinery and equipment assets and 6 for structures—that, taken together, comprise the non-residential portion of the capital stock. There are two major methodological issues that shape our econometric estimation of these summary rates: (1) the choice of aggregation technique that we have used when producing summary rates from individual assets, and (2) the inclusion/exclusion of certain zero prices when calculating these summary rates. We discuss these issues below.

2.C.1 Aggregating Asset Information to Produce Summary Depreciation Rates

Our exponential rates were generated via a "bottom-up" application of our MLS model. To create a summary rate for an asset group, we estimated separate rates of depreciation for the individual assets that make up the group, and then pooled this information (via taking a weighted average of asset lives) to arrive at the aggregate, or summary, depreciation rate. This technique was used to reduce heterogeneity bias and produces more efficient estimates.

2.C.2 Eliminating "Problem Zeros" from Asset Samples

Our econometric results for individual assets in Section 5 are based on used-asset samples that include both positive selling prices and discards, the latter yielding a zero-value for the survival ratio depicted in equation 7. In earlier presentations of this study, several experts on National Accounting expressed concern over the extent to which the presence of large numbers of discards (i.e., observations with zero prices) in our asset samples impacts the estimation of the capital stock. In principle, the inclusion of observations with zero-prices is critical to the estimation process because it alleviates the selection bias that would arises if depreciation rates were based solely on surviving assets. This said, there was some concern that a certain portion of these zero records may be spurious, and that this, in turn, would lead us to overestimate the depreciation rate.

To address this concern, we utilized generalized residual distributions to identify and eliminate (potentially) spurious zero-price observations. Our approach to generalized residuals is based on the technique developed by Lancaster (1985b) that was outlined in Appendix 2.B. The basic intuition behind our exercise is to make use of sample residuals to detect statistical differences between observations with zero prices and those with positive prices.

First, we computed the log of the generalized residuals from the full asset samples. (In doing so, we made use of some industrial detail, as the incidence of zero observations is correlated with industry membership). Next, these residuals were compared with results from the sub-samples generated from zero prices. Data from these sub-samples were eliminated unless differences between sub-samples were not statistically significant. Depreciation estimates were then based on the remaining observations. In the text on capital estimation in Section 2.6, we refer to this as the "reduced-sample" version of the MLS model.

2.C.3 Summary Rates of Depreciation from the Reduced-sample

Our method for generating depreciation rates from this reduced sample derives from a set of decision rules. Note that we applied these rules to individual assets prior to generating the aggregate asset groups.

First, we compared the MLS depreciation estimate from the full sample to those generated from the reduced sample derived from the elimination of potentially spurious zero-price observations. If these rates are similar, we selected the depreciation rate from the reduced-sample.

If, for a given asset, there existed significant differences between the full and reduced-sample econometric estimates, we then considered an *ex ante* (non-econometric) estimate based on the double-declining balance depreciation rate (i.e., a rate generated from recent survey information on the service life). This non-econometric *ex ante* rate was used in place of the econometric reduced-sample rate in cases where the former is less than latter. If these comparisons did not yield a clear choice of depreciation rate, then we selected the lowest depreciation estimate from among the three alternative methods—the MLS rate (full sample), the MLS rate (reduced sample) and the double-declining geometric rate. For individual assets with small numbers of observations, the double-declining rate was used. Last, a small number of adjustments were made to the final estimates.

Depreciation estimates for the capital stock exercise are reported below.

Table 2.C1 Depreciation Rates of Non-residential Assets

Asset Group		MLS (Full sample)	MLS (Reduced sample with adjustments)	Geometric DBR = 2	Geometric DBR = 1.65
1	Office Furniture, Furnishings	0.34	0.33	0.33	0.27
2	Computers and Office Equipment	0.59	(0.51, 0.58)*	0.43	0.35
3	Household and Services Machinery and Equipment	0.23	0.14	0.22	0.18
4	Electrical Industrial Machinery and Equipment	0.23	0.19	0.10	0.08
5	Non-Electrical Industrial Machinery and Equipment	0.28	0.22	0.27	0.22
6	Industrial Containers	0.08	0.05	0.21	0.17
7	Conveyors and Industrial Trucks	0.32	0.18	0.18	0.14
8	Automobiles and Buses	0.24	0.20	0.66	0.54
9	Trucks (excluding industrial trucks) and Trailers	0.25	0.20	0.36	0.29
10	Locomotives, Ships, Boats and Major Replacement Parts	0.16	0.12	0.11	0.09
11	Aircraft, Aircraft Engines and Other Major Replacement Parts	0.06	0.06	0.11	0.09
12	Communication Equipment	0.27	0.20	0.17	0.14
13	Other Equipment	0.21	0.20	0.21	0.10
14	Non-Residential Building Construction	0.08	0.07	0.08	0.04
15	Road, Highway and Airport Runway Construction	0.16	0.10	0.14	0.06
16	Gas and Oil Facility Construction	0.20	0.08	0.06	0.03
17	Electric Power, Dams and Irrigation Construction	0.15	0.06	0.06	0.03
18	Railway and Telecommunications Construction	0.11	0.10	0.12	0.05
19	Other Engineering Construction	0.24	0.08	0.07	0.03

* Separate estimates are made for goods and service industries, respectively.

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3

The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth

WULONG GU, MUSTAPHA KACI, JEAN-PIERRE MAYNARD AND MARY-ANNE SILLAMAA

3.1 Introduction

A key indicator of a nation's economic performance that is closely watched by economic analysts is productivity growth. In the long run, productivity growth is seen to be a key determinant of living standards. As a result, governments have adopted many different policies to provide businesses and workers incentives to improve productivity and international competitiveness. These have included accelerated depreciation allowances, subsidies for R&D, and support for innovative management practices that increase productive efficiency.

Statistics Canada publishes two main measures that track the growth of productivity in the business sector: labour productivity and multifactor productivity. Labour productivity is defined as output per unit of labour. Multifactor productivity (MFP) is defined as output per unit of combined capital and labour.

Labour productivity is a partial measure as it takes into account only one input—labour. Multifactor productivity measures are broader in that they capture the efficiency with which both capital and labour are used to produce output.

Labour productivity can increase either because there is a general improvement in efficiency or the amount of capital per unit of labour increases. Because multifactor productivity measures take into account both changes in labour and capital, they come closer to measuring just the increases in efficiency—where efficiency is defined broadly to include changes in plant size, organizational change, technological change and externalities.[1]

While labour productivity is a less comprehensive measure than multifactor productivity, some analysts feel labour productivity is more accurately estimated. It requires only measures of the growth in labour input, which can be derived in a relatively straightforward fashion from survey data. It continues to be used extensively in tracking the performance of the economy. The improvement in labour productivity over time is closely related to increases in workers' wages.

On the other hand, multifactor productivity measures require estimates of both labour and capital. Capital growth estimates require investment data, estimates of depreciation rates and length of life of assets. The latter are inherently more difficult to measure.

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[1] Some multifactor productivity estimates also attempt to isolate these various effects (see Baldwin et al, 2001, Chapter 8).

Regardless of these issues, both productivity measures are widely used to track changes in the economy and both require estimates of the growth in labour services that enter into the production process. Labour services can increase either because the number of hours worked increase or because the services of labour per hour worked increase, possibly because the labour force becomes more skilled and, therefore, more productive. In order to capture the latter effect, comprehensive measures of the growth in labour services need to be devised that take into account the relative productivity of different groups.

A commonly used measure of the growth in labour services that are applied to production is the rate of growth in total hours worked. Growth rates derived from this measure implicitly weight the growth in hours-worked of different categories of workers by the category's share of hours worked in the base period. Measures of the growth in the simple sum of total hours worked across all worker categories treats hours worked to be the same across different types of workers (the more educated versus the less educated, the more experienced versus the young, and men versus women). For example, when the simple sum of hours worked is used, an hour worked by a worker just out of school is considered to be equal to an hour worked by a worker with twenty years of experience.

An alternative measure of the growth in labour services recognizes the differences in workers' contributions to productivity and weights the growth in hours worked in different worker categories by their relative productivity. It is sometimes referred to as a quality-corrected measure of labour input.

The weights that are required for this exercise are generally derived from shares of total compensation accounted for by the category. The theory of the firm stipulates that, under certain conditions (the firm is a price-taker on labour markets and attempts to minimize its total costs), each category of labour will be hired up to the point where the cost of an additional hour of labour is just equal to the additional revenue that using this labour generates. In this case, the wage rate of the category will reflect its marginal productivity. This implies that, to get a measure of labour services that reflects differences in relative productivity, the individual hours of different quality can be weighted by the share of each type of labour in total labour compensation.

The differences in the growth of the weighted measure and the unweighted sum of hours worked across workers can be used to measure the effect of labour composition or labour quality on labour services growth. Labour quality or labour composition increases when hours worked by employees with high relatively wage rates (workers with more experience and education) increase faster than hours worked by employees with relatively low wage rates.

Taking account of changes in the composition of labour is important from several perspectives. First, it provides a measure of the contribution that increases in labour quality (due to increased shares of more educated and more experienced workers) make to production growth. Second, it has implications for growth accounting exercises that produce productivity estimates, where the growth in productivity is a residual derived from calculating the growth in output minus the growth of combined inputs.

Representing productivity as a 'Hicks-neutral' augmentation A_t of aggregate input, output can be written as:

$$Y_t = A_t F(K_t, L_t) . \tag{1}$$

Under the assumptions of competitive product and factor markets, and constant returns to scale, growth accounting gives the growth of output as the sum of the share-weighted growth of inputs and growth in multifactor productivity. Equivalently, multifactor productivity growth is the difference between the growth in output (Y) and combined inputs—labour (L) and capital (K).

$$MFP = \Delta \ln A_t = \Delta \ln Y_t - \bar{s}_{K,t} \Delta \ln K_t - \bar{s}_{L,t} \Delta \ln L_t , \tag{2}$$

where $\bar{s}_{K,t}$ is capital's average share of nominal value-added, $\bar{s}_{L,t}$ is labour's average share of nominal value-added, $\bar{s}_{K,t} + \bar{s}_{L,t} = 1$, the augmentation factor $\Delta \ln A_t$ captures multifactor productivity and Δ refers to a first difference.

Now consider two measures of labour change—the quality corrected measure ($\Delta \ln L_t$) and the measure that is not corrected ($\Delta \ln H_t$). If the hours worked in those worker categories whose wage share is above their hours share (whose relative wages rates are higher) grow faster than the hours worked in the lower wage categories, the quality adjusted labour services input ($\Delta \ln L_t$) will grow more quickly than a simple sum of the hours of all categories of workers ($\Delta \ln H_t$). In this case, using the quality adjusted measure of labour services to measure multifactor productivity growth in equation (2) will yield a lower estimate of productivity growth than using the simple sum of hours worked. Labour productivity growth that is measured as the growth of output per unweighted hour will partially reflect the contribution from labour compositional changes. Using the quality adjusted labour growth measure purges the productivity growth estimate of the effect of increasing skills by attributing part of the growth to this augmentation of skills.

Normally, changes in labour composition are minor in the short run, since the proportion of the workforce with a particular characteristic grows or declines slowly over time. Thus, short-run studies of changes in productivity that use unweighted estimates of the growth in labour services will not create a large distortion in the productivity estimates. But, in the long run, changing labour composition is more likely to occur. For example, over the last thirty years, there has been a dramatic change in the proportion of the labour force that is more educated and more experienced. Therefore, studies that examine long-run changes in productivity need to consider compositional changes in labour services.

Of course, the procedure for deriving a measure that weights the different categories by their relative productivity depends on the assumption that wage differentials broadly reflect differences in marginal productivity. While there will be disagreements about the categories where this is true, operating on the opposite assumption (that there are no differences across worker categories) is equally problematic. The choice facing statisticians is between a measure of labour services input like the sum of hours-worked that is less desirable conceptually, but possibly more accurately estimated, or a measure that is more sound in theory (the weighted sum of hours worked) but less precisely estimated.

In this chapter, we outline the methodology used to derive indices of labour services that account for differences in productivity across worker categories and then investigate the effect on standard measures of productivity when the alternate measure is used. The rest of the study is organized as follows. Section 3.2 provides an overview of the methodology that is used for measuring labour compositional change. Section 3.3 describes in more detail a labour composition index that was estimated from Canadian data with a method based on that of Jorgenson, Gollop and Fraumeni[2] (1987). Section 3.4 describes a labour composition index that was estimated from Canadian data using a Bureau of Labor Statistics (BLS) type (1993) method. The section also explains the differences in the two estimates. Section 3.5 compares U.S. and Canadian results for both methods. Section 3.6 examines the implications of labour compositional changes for labour productivity growth. Section 3.7 concludes the chapter.

3.2 Methods for Measuring Growth in Labour Services[3]

In this section, we present the index that will be used to measure the growth of labour services and changes therein that are due to changing labour composition. We then discuss two alternative approaches to estimating the Tornqvist index of labour services. The first approach is that proposed by JGF and more recently used by Ho and Jorgenson (1998). The second is based on the BLS approach.

3.2.1 Tornqvist Index of Growth in Labour and Changes in Labour Composition

The construction of the growth in labour services and changes in labour composition begins with a production function that relates output to labour and capital services:

$$Y_t = A_t F(K_t, L_t), \tag{3}$$

where Y_t is output (or value-added) in period t, L_t the index of labour services, K_t the index of capital services, and A_t is Hicks-neutral augmentation of aggregate input.

We assume that there are many types of labour inputs and capital inputs. The indices of labour and capital services are aggregated from the various types of labour and capital inputs. Labour services input can be expressed as a function of the hours worked of the various types of workers:

$$L_t = f(h_{lt}, \ldots, \mathrm{h}_{1t,} \ldots h_{Ct}), \tag{4}$$

where h_{lt}, $l = 1, \ldots, C$ is the number of hours worked by workers of type l. Similarly, capital services can be written as a function of the various types of capital inputs.

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[2] In the rest of this report, Jorgenson, Gollop and Fraumeni will be referred to as JGF.

[3] This section follows closely the section 2 of Ho and Jorgenson (1998) and the section 1 of Chinloy (1980).

Assuming that labour markets are competitive and production is characterized by constant returns to scale, we can write changes in labour services input as the weighted sum of changes in hours worked by the various types of workers:

$$\frac{\partial \ln L_t}{\partial t} = \sum_{l=1}^{C} \upsilon_{lt} \frac{\partial \ln h_{lt}}{\partial t} , \tag{5}$$

with

$$\upsilon_{lt} = \frac{\partial \ln f}{\partial \ln h_{lt}} = \frac{w_{lt} h_{lt}}{\sum_{l=1}^{C} w_{lt} h_{lt}} , \tag{6}$$

where υ_{lt} is the share of labour compensation attributed to the workers of type l, and w_{lt} is the hourly compensation rate of workers of type l. As workers' compensation rates equal their value of marginal product in competitive labour markets, weighting the hours of various types of workers by their compensation rates accounts for the difference in productive contribution across the types of workers.

The total number of hours worked is defined as the unweighted sum of hours worked across workers of various types:

$$H_t = \sum_{l=1}^{C} h_{lt} . \tag{7}$$

Let $\beta_{lt} = \frac{h_{lt}}{H_t}$ denote the share of worker type l in the total number of hours worked. The changes in the unweighted sum of hours worked can be written as:

$$\frac{\partial \ln H_t}{\partial t} = \sum_{l=1}^{C} \beta_{lt} \frac{\partial \ln h_{lt}}{\partial t} . \tag{8}$$

The difference between the changes in weighted sum and unweighted sum of hours worked is referred to herein as the compositional effect. Labour composition LC_t is defined as the ratio of labour services to hours worked:

$$LC_t = \frac{L_t}{H_t} . \tag{9}$$

Using the equations for changes in labour services and hours worked, we can write the changes in labour composition as:

$$\frac{\partial \ln LC_t}{\partial t} = \sum_{l=1}^{C} (\upsilon_{lt} - \beta_{lt}) \frac{\partial \ln h_{lt}}{\partial t} . \tag{10}$$

Increases in the hours of a worker contribute positively to labour composition if the worker receives relatively high wage rates. Increases in the hours of a worker contribute negatively to labour composition if the worker receives relatively low wage rates. Whether the weighted sum of hours worked grows more quickly than the unweighted sum depends upon whether the wage share of the category is larger than the hours share *and* whether the rate of growth in hours is above the mean—that is whether the larger weights $(\upsilon_{lt} - \beta_{lt})$ in equation (10) are applied to faster growing categories.

These equations express changes in a continuous form. Implementation of equations (5) and (10) for estimating labour services input and labour composition over discrete time periods requires the specification of an aggregation function of labour services input. When the aggregation function is of a translog form, we obtain a Tornqvist index of labour services input and labour composition. The Tornqvist index of labour services input can be written as:

$$\Delta \ln L_t = \sum_{l=1}^{C} \bar{\upsilon}_{lt} \Delta \ln h_{lt} \ . \qquad (11)$$

Where Δ denotes changes between periods $t-1$ and t , and the weights for aggregating hours of the various types of workers are the average compensation share of the worker type:

$$\bar{\upsilon}_{lt} = \frac{1}{2}\left(\upsilon_{lt} + \upsilon_{l(t-1)}\right). \qquad (12)$$

The growth of hours worked, defined previously in continuous form, can be written in discrete time more simply as:

$$\Delta \ln H_t = \Delta \ln \sum_{l=1}^{C} h_{lt} \ . \qquad (13)$$

It follows directly from equations (11) and (13) that the logarithmic change in labour composition can be represented by the following formula:

$$\Delta \ln LC_t = \Delta \ln L_t - \Delta \ln H_t = \sum_{l=1}^{C} \bar{\upsilon}_l \Delta \ln h_{lt} - \Delta \ln \sum_{l=1}^{C} h_{lt} \ . \qquad (14)$$

The labour composition indices are constructed from the antilogarithms of this differential. The growth of labour composition is the difference between the weighted and unweighted growth rates of hours worked. Labour quality is said to increase when the labour services input grows faster than total hours worked, when the composition effect is positive. This will occur when the proportion of workers with relatively high earnings (better-educated, more experienced workers) increases. In contrast, labour quality declines when the proportion of such workers decreases, when the composition effect is negative.

To identify the contribution to labour input that is made by shifts in the proportion of workers with particular characteristics such as gender, age, education and employment class separately, we construct the partial indices of labour services input corresponding to these worker characteristics based on a decomposition analysis. For this purpose, we denote $\{H_{saec}\}$ the components of hours worked, classified by gender s, age a, education e, and employment class c. We also consider shares of these components in the value of labour compensation $\{v_{saec}\}$. A partial index of labour input corresponding to, for example, gender, is defined as follows:

$$\Delta \ln L^{gender} = \sum_{s} \bar{v}_s \Delta \ln h_s \,, \tag{15}$$

$$= \sum_{s} \bar{v}_s \Delta \ln \left(\sum_{a} \sum_{e} \sum_{c} h_{saec} \right),$$

where:

$$\bar{v}_s = \frac{1}{2}\left[v_s(t) + v_s(t-1) \right],$$

$$v_s = \sum_{a} \sum_{e} \sum_{c} v_{saec} \,.$$

The partial index of labour services growth corresponding to gender captures substitution between the two sexes alone. Similarly, the partial input index for age, education or employment class measures substitution between age groups, educational attainment levels or employment classes.

As in most decomposition analyses, the sum of the individual components do not add perfectly to the total, because the individual components do not allow for substitution across categories.

The growth rate of the partial index of labour composition is the difference between the growth rates of partial labour services input index and hours worked.

3.2.2 Two Empirical Approaches to Estimating Growth in Labour Services and the Effect of Changing Labour Composition

In practice, there have been two related but different approaches used to estimate the growth in quality-adjusted labour services by weighting the growth in hours of work across various types of workers by their wage shares.

First, JGF (1987) have constructed labour services input indices for 51 industries and for the American economy as a whole for the 1947-1979 period. Their measure takes into account the changes that occur in labour composition by considering differences in growth rates in hours worked across categories that are defined by age, gender, level of education, class of worker and occupation. Average wage rates and income shares are calculated for workers grouped into strata defined by these characteristics.

Second, the U.S. Bureau of Labor Statistics (BLS, 1993) has developed an alternative measure of labour input for the business sector. The measure represents a rising average level of worker skills as measured by education and experience for each gender. The BLS has used statistical regression analysis to isolate the impact of education and experience on wage rates. They incorporate in their analysis socio-demographic factors such as level of education, experience, birth rate and female labour force participation.[4] They then use the predicted wage rate from their regression to calculate wage shares. Since 1993, the official BLS multifactor productivity measure for the business sector (but not for individual industries) has been adjusted for changes in labour composition.

Both the JGF and the BLS approaches begin with the construction of hours worked and earning weights by strata that are defined by particular worker characteristics. The main differences between the two approaches relate to the enumeration of possible worker types and the manner of the construction of earning weights.[5]

Worker types. JGF uses five characteristics of workers: education, age, gender, employment class (paid vs self-employed), and occupation. Ho and Jorgenson (1998) drop the occupation characteristic in their extension of JGF (1987), since JGF found that the occupation mix had little effect on the labour composition index once the other four worker characteristics were taken into account.

On the other hand, the BLS uses three worker characteristics: education, work experience and gender. The BLS does not separate paid and self-employed workers. The education variable in the BLS approach is defined for seven schooling groups, whereas the levels of schooling considered by JGF consist of five groups.

JGF uses a worker's age variable to measure the level of on-the-job training and productivity differences between workers. The BLS replaces this age variable in the JGF approach with work experience—a variable that is imputed from age. Work experience for men is found to be reasonably well predicted by the commonly used potential experience (age minus years of schooling minus 6). However, potential experience was found to be a poor proxy for actual experience in women, due to low rates of labour force participation in the early post-war period and during childbearing years.

The BLS chooses to estimate experience equations for men and women using actual work histories from linked Current Population Surveys (CPS)/ Social Security Administration (SSA) data set for 1973. The file links individual records from the SSA files and the March 1973 CPS. Explanatory variables in the experience equation for men include potential experience, years of schooling, and interactions between potential experience and years of schooling. For women, explanatory variables include the variables in the men's experience equation plus marital status and the number of children ever born. The fitted experience equations from the 1973 CPS/SSA data set are then used to estimate work experience for other years.

Earning weights. Both the JGF and the BLS approaches make use of household surveys and the population census to estimate relative earnings of the various types of workers. JGF earning weights are estimated as survey sample averages for all persons of a given characteristic. In contrast, the BLS earning weights are based on wage models estimated from the Population Censuses for 1950 and 1960 and annually from the CPS

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[4] For a general survey of the literature on the subject, see Dean and Harper (1998).

[5] For a comprehensive discussion of similarities and differences between the two approaches, see Appendix A and F of BLS (1993).

beginning in 1968. Weights for other years are derived from linear interpolation of the estimated parameters.

The BLS argues that the difference in the simple average of wage rates between two types of workers that are used in the JGF approach reflects not only the characteristics identifying the groups (such as experience and education) but that it also reflects other characteristics that are not used to identify groups that are highly correlated with these characteristics. For example, wage differentials across education classes may be the result of parental background rather than of educational training. As such a simple wage differential between two educational classes overstates the effects of the differences in qualifications. This argument is equivalent to the argument that the JGF approach is using a wage function that only considers education and is misspecified.

The wage equation approach that is used by the BLS to predict wages for a particular characteristic like education tries to isolate only the wage differentials associated with work experience and educational attainment; and the resulting index of labour composition based on estimated wages from the multivariate analysis attempts to provide a more precise estimate of the marginal contribution of experience and education to labour services growth.

Canada: In Canada, the existing measure of labour services input for the business sector that is used in Statistics Canada's productivity program is constructed by aggregating the hours of work across industries by their wage bill shares. This measure takes into account the differences in worker characteristics across industries. A number of recent papers (Coulombe, 2000; Diewert, 2000) have suggested that more detailed official estimates of changing labour compositional changes are needed. This chapter provides these estimates.

There are several precursors to this exercise. Dougherty (1992) devised labour services input indices for Canada and the other G7 countries for the 1960-1989 period. These labour services input indices are aggregated from workers broken down by level of education and employment category. Jorgenson and Yip (1998) experimented with extending the analysis to cover the 1960-1995 period, but did not use as comprehensive a set of source data as are used in this chapter. Gu and Maynard (2001) experimented with more comprehensive data and the JGF approach to construct a preliminary measure of labour services input for the business sector and individual industries from1961-1995.

In this chapter, we finalize the preliminary estimates of Gu and Maynard (2001) and estimate labour services input indices for a more recent period. We also examine the robustness of labour services input estimates by employing an alternate method—a BLS-type estimator. The BLS (1993) reports that there is a considerable difference between the U.S. estimates that are yielded by the BLS approach and those yielded by the Jorgenson method. Therefore, we examine how sensitive measures of the growth in Canadian labour services are to the two methods that are used in constructing the U.S. labour services input measures.

Table 3.1 Worker Classifications

Labour Characteristics	Number of Categories	Description
Gender	2	Female; male
Age Group	7	15-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education	4	Primary; secondary; post secondary; university
Class of Workers	2	Paid workers; other categories

3.3. Estimating Canadian Labour Compositional Change with the JGF Method

In this section we describe the Canadian data that are used for the analysis and present the indices of labour composition for the business sector and individual industries using the JGF method.

3.3.1 Constructing the Labour Composition Index

To estimate indices of labour services input and labour composition, we disaggregate workers by gender, seven age groups, four education levels and two employment categories for a total of 112 types of worker (Table 3.1). Two sets of data are used to construct consistent estimates of hours worked and labour compensation for each of the characteristics considered:

– data from Statistics Canada’s productivity database by industry and employment category (paid workers, self-employed workers and unpaid family workers) for every year since 1961; and

– data by industry, class of worker, age, gender and level of schooling that was constructed from the Census of Population and various household surveys (Labour Force Survey (LFS); Survey of Consumer Finances (SCF); and Survey of Labour and Income Dynamics (SLID)).

Data on hours worked and earnings by industry and employment categories from Statistics Canada’s productivity database. The concept of hours worked for the Statistics Canada’s productivity program is essentially the one recommended in the 1993 System of National Accounts (SNA) manual. Hours worked are derived from the total number of hours that a person spends at work, whether they are paid hours or not.[6] In general, it encompasses both regular hours and overtime, including breaks, travel time, on-the-job training time and time lost because of temporary stoppages during which employees remain at their posts. Hours worked do not include time lost due to strikes or lockouts, annual vacations, statutory holidays, sick leave, maternity leave or leave for personal responsibilities.

Estimates of hours-worked are broken down into three main employment categories: paid employment, self-employment and unpaid family employment. The latter occurs mostly in industries with significant numbers of family businesses (primarily agriculture and retail trade).

For productivity calculations at Statistics Canada, the number of hours worked is obtained by multiplying the number of jobs by the average annual hours worked. In general, estimates of the number of paid jobs are based on combined employment data from household surveys (LFS; SLID; and censuses) and business surveys (Survey of

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[6] Those who are not at work but are paid are included in the total.

Employment, Payrolls and Hours, Annual Survey of Manufactures, Census of Mines, etc.). Data for other employment categories are taken directly from the LFS. Except for some mining and manufacturing industries, all data on average hours worked also come from the LFS. Data on hours worked by sector and by industry are consistent with the System of National Accounts and are adjusted for known statistical discontinuities.

Labour compensation as defined for the productivity program includes all payments in cash or in kind that Canadian producers make to workers in return for their services. It includes labour income such as wages and salaries (including bonuses, tips, taxable allowances and backpay), supplementary income of paid workers (various employer contributions) and the implicit labour income of self-employed workers.

The hourly earnings of workers are given by the quotient of total compensation paid for all jobs divided by total hours worked.

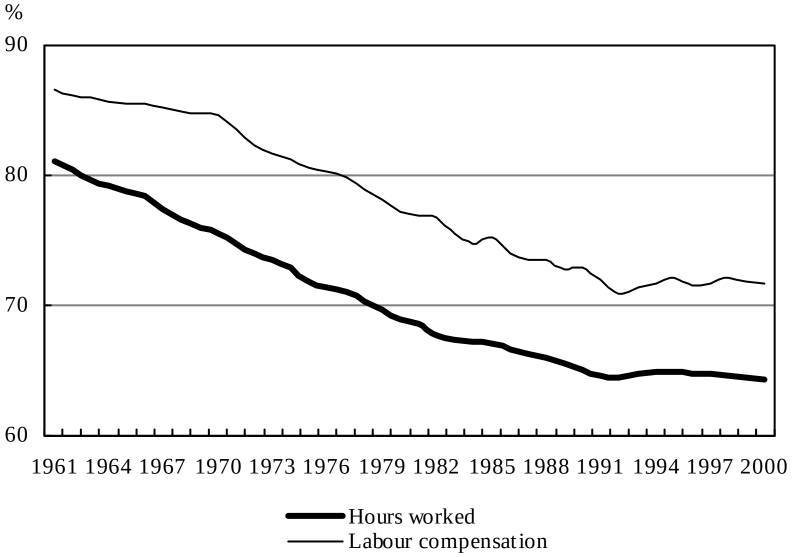
Income data for all paid employment originate directly from the estimates of employment income produced by Income and Expenditure Accounts. In the case of self-employed workers, combined labour income is obtained by imputation, using the assumption that the value of an hour worked by a self-employed worker is equal to the value of an hour worked by a paid worker (at the average rate) in the same industry. The same imputation approach is used to produce data for unpaid family workers. In addition, employment income for certain professionals (physicians, lawyers, dentists, accountants and engineers) is derived from income tax statistics (Revenue Canada, Catalogue No. RV 44).

Data on hours worked and earnings by industry, gender, age group, education and employment categories from household surveys and the population census. Data from the 1961, 1971, 1981, 1986, 1991 and 1996 censuses of population were used to construct hours worked and labour compensation for the census reference years (1961, 1970, 1980, 1985, 1990, 1995). For the non-census years prior to 1976, data on hours worked and earnings are estimated from a linear interpolation of the data from two adjacent Censuses. After 1976, the hours data derived from a linear interpolation of the two adjacent Censuses are reconciled with the data on hours worked by worker characteristics in the aggregate business sector from LFS. The hourly earnings data derived from a linear interpolation of the two adjacent Censuses are adjusted to the hourly earning estimates from the two household surveys: SCF over the 1976-1993 period; and SLID after 1993.

In January 1990, the LFS revised the questions related to educational attainments of the respondents. From 1976 to 1989, post-secondary education was limited to education that normally requires high-school graduation. After 1990, post-secondary education included any education that could be counted towards a degree, certificate or diploma from educational institutions. The change caused a reallocation of respondents from secondary to post-secondary education. To ensure the data is consistent over time, we chose not to use the pre-1990 data on hours worked by education from the LFS. The data on hours worked by education prior to 1990 was calculated instead as a linear interpolation of the two adjacent Censuses.

Since 1961 Census data are not available in electronic form, the iterative proportional fitting method (see JGF (1987)) was used to estimate data on hours worked and hourly earnings by industry, gender, age group, education and employment classes (see Gu and Maynard, 2001 for details).

Figure 3.1 Share of Labour Compensation and Hours by Male Workers in the Business Sector



Combining the data from household surveys and the population census with the estimates of the productivity program. The data on hours worked and earnings that are constructed from household surveys and the Census of Population are reconciled with the annual benchmark data used in Statistics Canada's productivity program. The two sets of data were reconciled using their common variables (industry and class of worker category). Constructing the hours-worked data required reconciliation since number of hours worked derived from the Census refers to the census week while earnings and number of weeks worked refer to the previous year. Hours worked are computed by multiplying the average hours worked during the census reference week by the number of weeks worked the previous year.

Once the data on annual hours worked and hourly earnings by industry, age group, gender, level of education and employment category were collected, the indices of labour composition were constructed for the business sector over the 1961-2000 period.

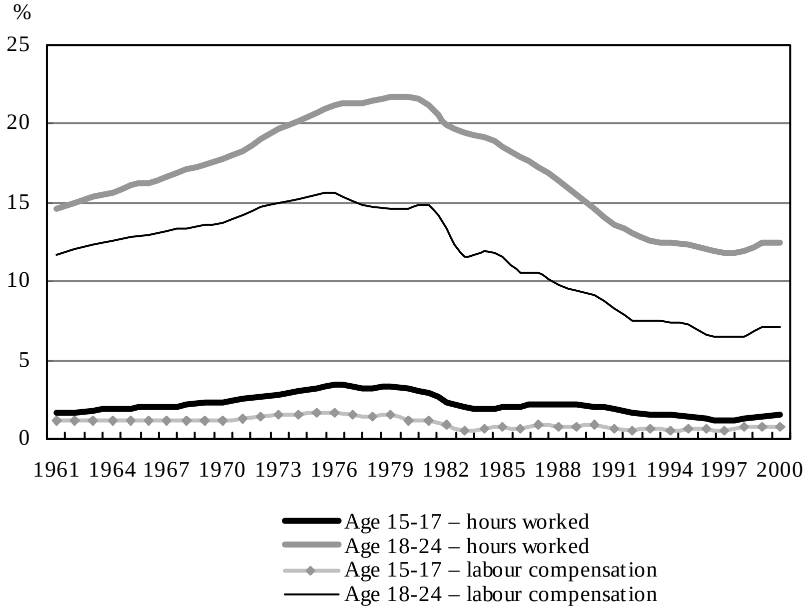
3.3.2 Trends in the Composition of Hours Worked in the Business Sector

Before examining the effect of considering all factors (education, age, gender, and class of worker) together, we first present the trend in the shares and relative wage rates of each factor taken by itself.

The contribution of the change in the composition of hours worked to labour input can be either positive or negative for each category—gender, age, level of education and employment category. In this section, we present summary data that will reveal the effect of the changing composition of the labour force on our estimate of the growth in labour services.

In what follows, we examine changes in the relative importance of a type of workers over the time period using both the wage share and the hours share of each type of worker. If the wage share is greater than the hours share of a particular category, then the growth rate of labour services that takes into account wage differences will weight that category (i.e. educated workers) more heavily than the estimate that just uses the straight sum of hours worked. And if that category (i.e. educated workers) has higher

Figure 3.2 Share of Labour Compensation and HoursWorked by Age Group in the Business Sector: Ages 15-17 and 18-24



than average growth (as evidenced by a growth in the share of hours-worked of that category), then the wage-weighted rate of growth of labour services will have a higher rate of growth than the rate of growth that is derived from the simple sum of hours-worked, which implicitly weights each category's rate of growth by its share of hours-worked. If the category has a lower than average growth rate, the opposite will occur.

3.3.2.1 Gender

Figure 3.1 shows the change in the share of hours worked by male workers in the business sector between 1961 and 2000. Over that period, the share of hours worked by men declined from 81.0% in 1961 to 64.3% in 2000. The male worker on average receives a higher wage than does a female worker and consequently the wage share of male workers is higher than their hours share. The combination of a lower rate of growth for hours worked by male workers and the higher wage share means that the growth rate in the weighted labour input that takes into the gender composition of the labour force will be lower than the unweighted estimate. The feminization of the labour force will have a slight dampening effect on labour composition growth.

3.3.2.2 Age Group

Hours worked by age group in the Canadian business sector have changed substantially over the last forty years (Figures 3.2, 3.3, and 3.4). The 1971-1980 period was characterized by the entry of younger workers—the post-war baby-boomers to the workforce. Since age is a proxy for experience, this period was marked by a general decrease in the average experience of the labour force.

The share of hours worked by the 15-17 and 18-24 age groups rose steadily between 1961 and 1980. There was also a relatively large increase in the size of the 25-34 age group in the 1970s as the baby boomers entered the workforce. On the other hand, between 1961 and 1980, the share of hours worked for the 35-44 and 45-54 age groups declined.

Figure 3.3 Share of Labour Compensation and Hours Worked by Age Group in the Business Sector: Ages 25-34 and 35-44

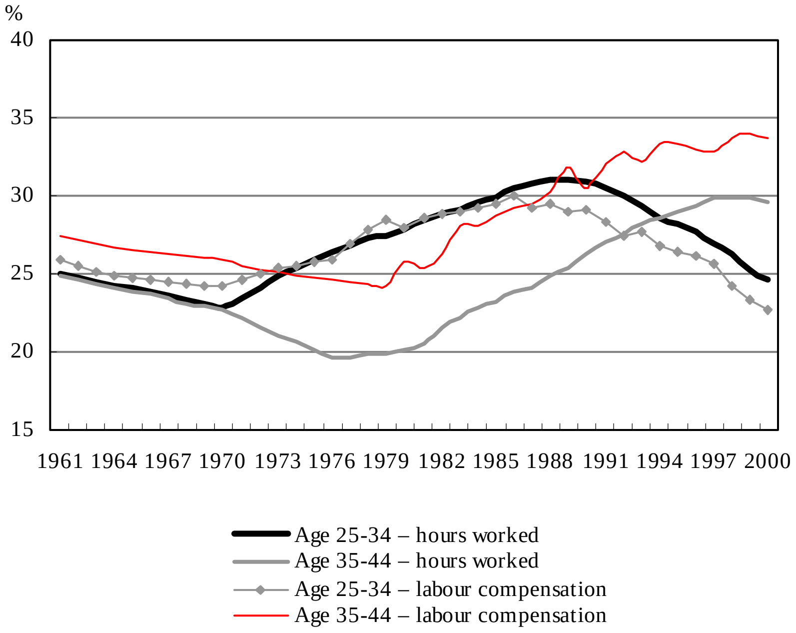
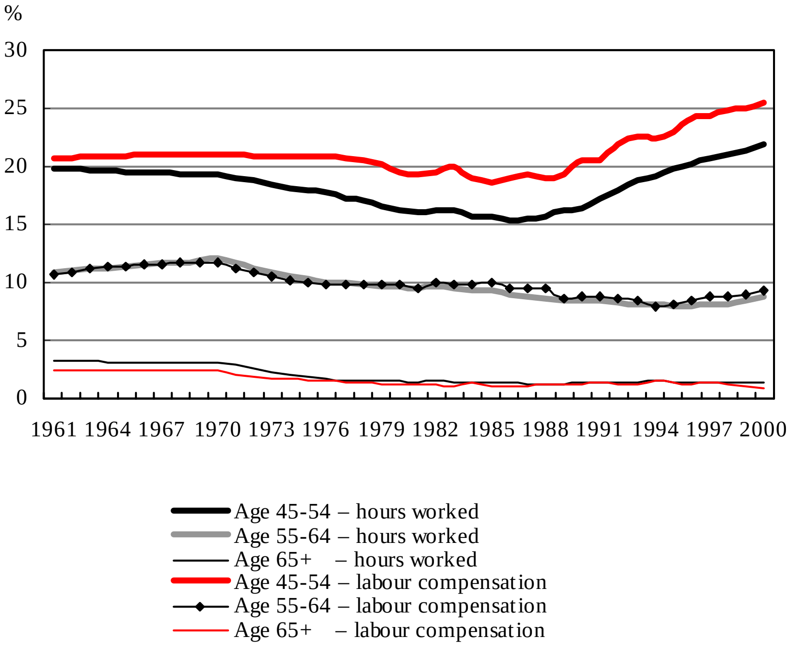


Figure 3.4 Share of Labour Compensation and Hours Worked by Age Group in the Business Sector: Ages 45-54, 55-64 and 65+



The trend towards a less-experienced workforce reversed itself in the early 1980s, when the baby-boomers entered the 35-44 age group. Between 1980 and 2000, the share of hours worked for the 15-17 age group dropped from 3.1% to 1.5%, and for the 18-24 group from 21.7% to 12.4%. Over the same period, the share of hours worked for the 35-44 group increased from 20.1% to 29.6%, and for the 45-54 group from 16.3% to 21.9%.

Relative wage rates differ across these groups, with the young receiving a lower than average wage and the older more experienced worker receiving higher wages. Throughout the period, the share of compensation going to the 15 to 24 year-old group is constantly below that of their hours worked. On the other hand, the share of compensation going to the 35 to 44 year-old group was above their hours worked and the difference increased before the early 1980s and showed slight declines afterwards. The same is the case for the 45 to 54 year-old group, though here the differential increased before the early 1980s and showed little changes thereafter.

Together the lower wage share of younger workers and their higher rates of hours growth in the earlier period means that a labour measure that weights hours-worked by relative wage share will grow less quickly in the period from 1961-1980. On the other hand, it will grow more quickly subsequently. We should therefore expect the effect of age, a proxy for experience, to have changed over time. It should be negative in the early period and increasing later.

3.3.2.3 Education

Levels of education have risen steadily since the 1960s. Figures 3.5 and 3.6 show that the share of hours worked by those with the two highest levels of educational attainment have increased over time. The share of hours worked by workers with a post-secondary education rose from 2.9% in 1961 to 42.8% in 2000. Over the same period, the share held by workers with a university education climbed from 3.3% to 15.5%.

Figures 3.5 and 3.6 also show that the share of wages for these two groups is higher than their share of hours worked. Thus, taking into account labour composition will give a higher weight to the two categories that are growing most rapidly. As such, the compositional effect due to education should be positive.

It is also useful to note that the relative importance of these weights has changed over time. In the period up to 1981, the wage share of the two groups with post-secondary or university education was considerably above their hours-worked share. While this continues for the university educated after 1981, this is no longer the case for the post-secondary group in this period. This will reduce the compositional effect due to improvements in education later in the period.

3.3.2.4 Employment Category

The last category considered is paid versus unpaid workers. As in Ho and Jorgenson (1998), we grouped unpaid family workers and self-employed workers together in the same employment category.

Figure 3.7 shows that the share of total hours worked by paid workers climbed steadily between 1961 and the late 1980s. The trend was particularly strong before 1975. After the late 1980s, the share of paid workers declined, while the share of workers other than paid workers increased.

Figure 3.5 Share of Labour Compensation and Hours Worked by Education Attainment in the Business Sector: Primary and Secondary

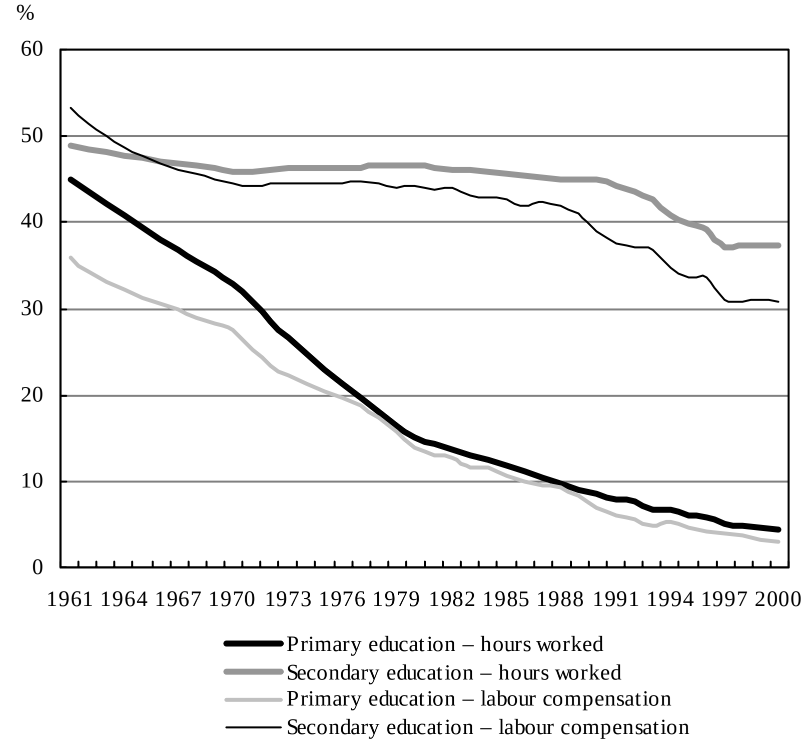


Figure 3.6 Share of Labour Compensation and Hours Worked by Education Attainment in the Business Sector: Post-secondary and University

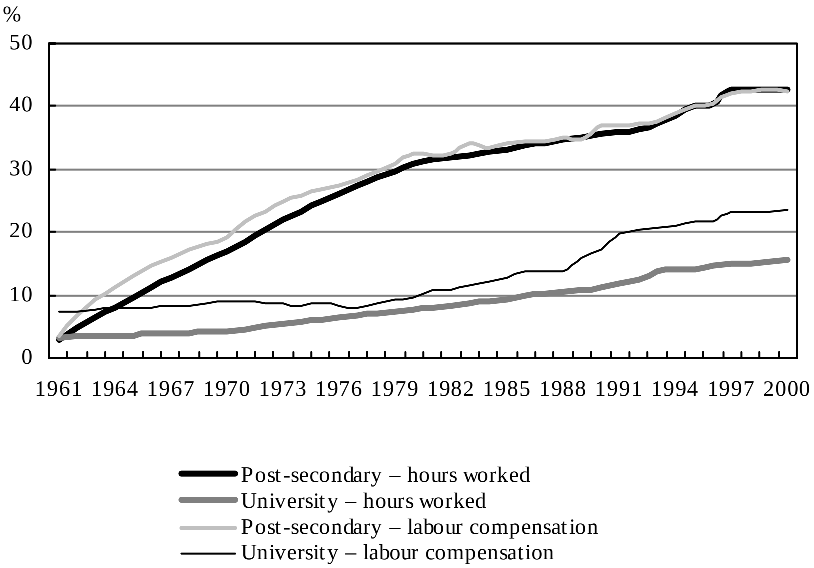
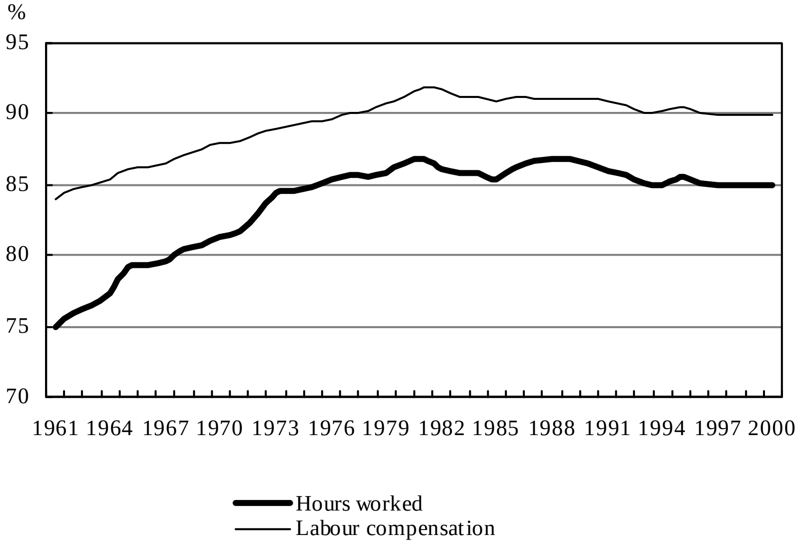


Figure 3.7 Share of Labour Compensation and Hours Worked by Paid Workers in the Business Sector



The share of wages going to paid workers is slightly higher than their share of hours worked. This means that higher growth in paid workers in the period prior to the 1990s will make a slight contribution to the growth in the composition effect. On the other hand, it will slow the growth in the composition effect in the 1990s.

3.3.3 Trends in the Growth of Labour Composition in the Business Sector

The results of applying Jorgenson's methodology, that is, of estimating the annual growth rates of labour input, hours worked and labour composition in the business sector over the 1961-2000 period and selected intervals within that period, are summarized in Table 3.2. The table contains the rate of growth of unweighted hours worked—what is normally used in productivity studies—and the average weighted growth rate. The difference is the effect of compositional change. We also include the marginal effect of each factor.

With the changing composition taken into account, the growth rates of labour input are higher than the growth in the straight sum of hours worked. The average annual growth rates in weighted hours worked were 2.75%, 2.01%, 2.63%, 1.17% and 3.48% over the periods 1961-1973, 1973-1979, 1979-1988, 1988-1995 and 1995-2000, while the growth rates derived using the straight sum of hours worked were 1.90%, 1.92%, 2.04%, 0.27% and 3.05%, respectively.

The increases due to increasing quality or changes in labour composition were substantial: they averaged 0.62% a year for the entire period, but fluctuated considerably from period to period: 0.84% for 1961-1973, 0.09% for 1973-1979, 0.59% for 1979-1988, 0.89% for 1988-1995, and 0.43% for 1995-2000. The increase in labour composition growth was slowest in the period that coincided with the entry of baby-boomers and the rapid increase of women in the workforce.

Figure 3.8 Indices of Labour Input, Hours Worked and Labour Composition in the Business Sector

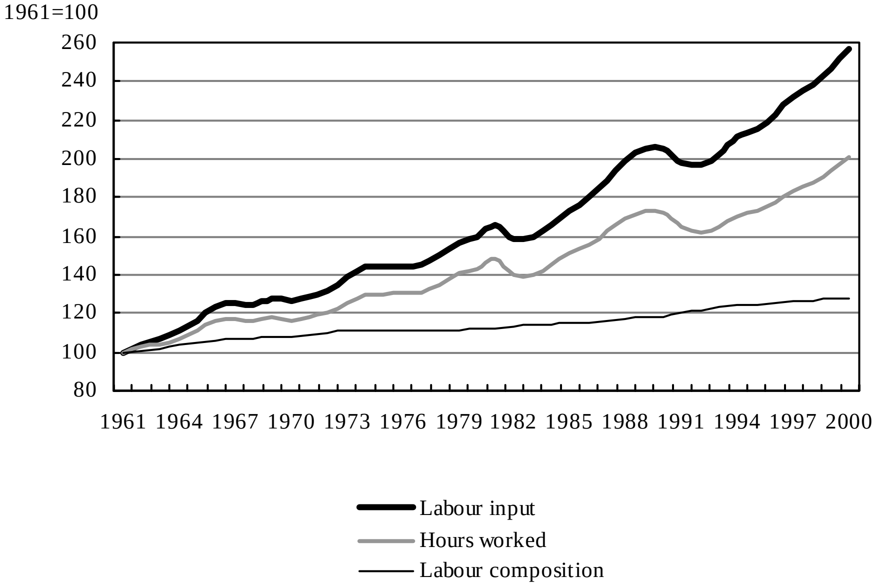


Figure 3.9 Partial Indices of Labour Composition in the Business Sector

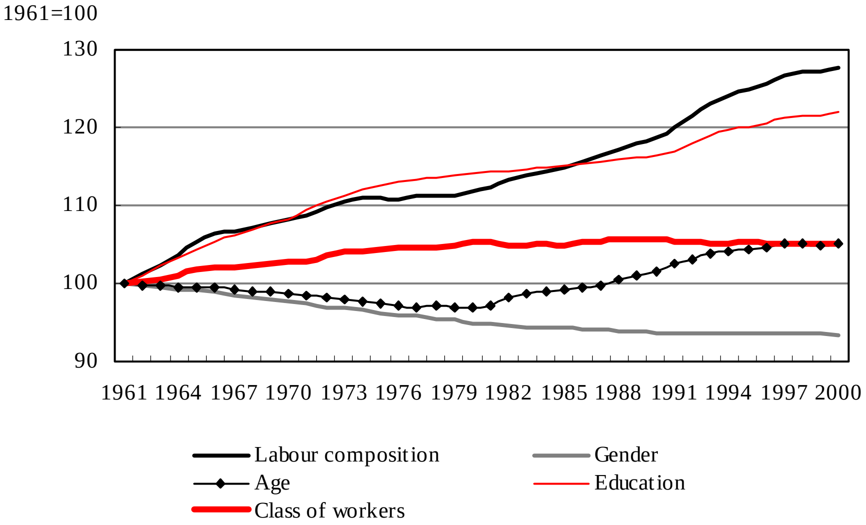


Table 3.2 Annual Changes in Labour Input, Hours and Labour Composition for Business Sector (Percent)

		Subperiods				
	1961-2000	1961-1973	1973-1979	1979-1988	1988-1995	1995-2000
Labour Input	2.42	2.75	2.01	2.63	1.17	3.48
Hours	1.79	1.90	1.92	2.04	0.27	3.05
Labour Composition	0.62	0.84	0.09	0.59	0.89	0.43
Partial Indices of Labour Composition						
Gender	-0.17	-0.27	-0.26	-0.16	-0.06	-0.04
Age	0.13	-0.17	-0.19	0.40	0.54	0.14
Education	0.51	0.89	0.36	0.21	0.51	0.30
Class of Worker	0.13	0.34	0.11	0.09	-0.04	-0.05

Note: Changes in labour composition plus changes in hours worked may not add to changes in labour input due to rounding.

The movement of the indices of labour input, hours worked and labour composition in the business sector between 1961 and 2000 are plotted in Figure 3.8. Over the entire study period, labour composition accounted for an average of 25.6% of labour input (30.5% for 1961-1973, 4.5% for 1973-1979, 22.4% for 1979-1988, 76.1% for 1988-1995, and 12.4% for 1995-2000). The pace of the growth in labour composition increased in the 1988-1995 period to a level three times as high as the growth rate of hours worked (0.89% compared with 0.27%).

The relative impact of education, age, gender, and class of worker is presented in the bottom half of Table 3.2 and in Figure 3.9. Rising education attainment is the main factor in making labour composition growth positive. It accounts for most of the impact of changing labour composition in each period.

The second most important factor is age of worker—a proxy for experience. Over the whole period, its average effect is not large; but it had a negative impact in the 1960s and 1970s when the growth in younger workers was faster than for more experienced workers. There was a positive impact on labour composition after the 1980s from changes in age composition when the reverse was true.

The changing male/female composition had a dampening effect on labour composition. But the effect was not large.

Finally, movement away from self-employment to paid employment generally had a positive effect on the growth of labour. However, the impact of this variable was largest in the 1960s. In more recent years, with the growth in self-employment, there has been a slight negative effect resulting from the shift that has taken place from paid and self-employed status.

We have also calculated the index of labour composition for the individual industries at the L-level industry aggregation, as shown in Appendix Table 3.A1. Over the 1961-1997 period, the growth in labour composition was positive in 132 of the 147 industries of the Canadian business sector. Annual growth of labour composition over the period ranges from -1.32% to +1.61%.

Table 3.3 Worker Classifications

Labour Characteristics	Number of Categories	Description
Gender	2	Female; male
Age	60	Individual years 15-85; all others excluded
Education	4	Any primary; any secondary; any post secondary excluding university graduates; university graduates

3.4. Estimating Canadian Labour Compositional Change with a BLS-style Method

This section examines the sensitivity of the labour compositional change to an alternate estimation technique—that of the Bureau of Labor Statistics. The BLS (1993) reports substantial differences in the final estimates that are produced by their method and that of JGH (1987).

3.4.1 Constructing the Labour Composition Index

Central to the BLS approach are estimated wage functions that are used to estimate wage shares. These are derived for Canada from data on hours worked, hourly earnings, and the characteristics for individuals taken from microdata that comes from the Censuses of Population for 1971, 1981, 1986, 1991, and 1996. To be comparable to U.S. BLS results, only workers in the private business sector were included. For the regression, workers were disaggregated by gender, age, and four education levels for a total of 480 types of worker (Table 3.3).

Estimating hours worked. Since annual hours worked is not provided directly in the Census, it was calculated as the number of weeks worked by the individual at their primary job in the year preceding the Census times the number of hours worked during the Census week.[7] A limit of 4,500 hours per year was imposed on the calculation. People with zero calculated hours were eliminated.

Estimating hourly earnings. Paid employees and incorporated self-employed individuals were segregated into two groups for the purpose of estimating hourly earnings. The average hourly earnings (average wage rate) for each category of these workers was calculated as the quotient of total annual compensation paid the workers over the estimate of total annual hours worked.

The log wage rate was then regressed against a linear specification consisting of age, age squared, education level dummy variables, and other personal characteristic dummies that could be defined from the Census databases. While the BLS makes use of an elaborate procedure to predict experience from age, they also report that making use of age alone produces almost the same results. Therefore, we adopted the latter approach. Separate regressions were run for men and women. Detailed regression results are presented in Appendix Tables 3.A2 and 3.A3.

The results for the five different years show several interesting trends. First the coefficient on age gradually increases over time for women, but not for men. However, when the nonlinearity is taken into account and the age premium for twenty years experience is calculated from these coefficients (Table 3.4), it is clear that the advantage enjoyed by older male and females increases between 1970 and 1995—though it increases more for women.

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[7] The calculation was approximate for the 1971 Census because only a range of weeks worked and a range of hours worked were available for each individual.

Table 3.4 Education and Age Premiums for Men and Women in the Business Sector

	1970	1980	1985	1990	1995
Men					
Any University Degree vs. Any High School Premium	43.1	35.1	33.5	38.3	38.7
Age 40 vs. Age 20 Premium	39.8	43.6	53.8	50.2	52.2
Women					
Any University Degree vs. Any High School Premium	33.0	31.9	29.5	38.5	39.2
Age 40 vs. Age 20 Premium	14.8	27.4	39.4	36.2	42.6

The elementary school disadvantage relative to high school also increases over time and once more this is greater for women than for men. Having a post-secondary degree or a university degree also becomes more important over time for women, but less so for men. Indeed the premium for university for men stays relatively constant though it increases for women.

Other socio-economic characteristics are significant. Being married increases the wage rate, but more for men than women. In the former case, the marriage premium falls over time. Being in a large city provides a higher wage, more so for women than for men. The greater the number of children, the lower is the wage. And this matters more for women than for men. Immigrants receive lower wages, especially if they are recent arrivals. Speaking a different language at home than is used at work is also associated with a lower wage rate. Part-time workers receive lower wages as well. There are also substantial industry differences, with the premium on financial and banking services increasing over time.

More important, we find that the removal of all socio-economic characteristics but the age and education variables has the effect of lowering the education and age premiums. But the effect is not large. As such, labour compositional changes estimated using the BLS and JGF methods should be similar.

The estimated coefficients were then used to derive separate predicted wage rates for men and women using the formula below:

Predicted wage rate = (new intercept) + (regression-coefficient-for-age x age) + (regression-coefficient-for-age-squared x age-squared) + (regression-coefficient-for-elementary-education-dummy x elementary-education-dummy) + (regression-coefficient-for-postsecondary-education-dummy x post-secondary-education-dummy) + (regression-coefficient-for-university-degree-dummy x university-degree-dummy).

The intercept for this equation was calculated as the sum of the estimated intercept plus the sum of the products of the remaining regression coefficients times the proportion of the regression sample with that characteristic.

Predicted wage rates were calculated for all workers in the Census, whether paid, unpaid, or self-employed, who had positive annual hours. Predicted incomes for each individual were calculated as the product of the predicted wage rate and annual hours. Predicted wage shares for each category of worker (stratified by the age, education, gender categories outlined in Table 3.3) were calculated as the quotient of the predicted income for the category divided by the total predicted income over all categories.

Table 3.5 Average Annual Growth of Labour Composition in the Canadian Business Sector (Percent): A Comparison of JGF and BLS Methods

Period	JGF Method (1)	BLS Method (2)	BLS Categories and Data, JGF Weights (3)	BLS Data and Weights, JGF Age Categories (4)	BLS Data and JGF Weights and JGF Age Categories (5)
1970-1995	0.57	0.45	0.58	0.43	0.56
Subperiods					
1970-1980	0.33	0.34	0.46	0.33	0.45
1980-1985	0.51	0.22	0.37	0.22	0.36
1985-1990	0.68	0.63	0.82	0.57	0.75
1990-1995	1.00	0.72	0.81	0.68	0.77

Changes in labour services input, total hours worked, and labour composition were then calculated in the same manner as in the Canadian JGF approach described in earlier sections, the differences being that it is the estimated rather than the actual wages that are employed and that the strata are slightly different.

3.4.2 A Comparison of changes in the labour composition index for the business sector using JGF and the BLS

The average annual growth of labour composition estimated using the BLS method is presented in Column 2 of Table 3.5 along with a comparison to estimates using the JGF method (Table 3.5, column 1).

The JGF method generally produces a slightly higher growth of labour composition in the Canadian business sector over the 1970-1995 period than the BLS method, but the results are close for the 1970-1980 and 1985-1990 periods. Moreover, they are much closer than the two U.S. results that differ by about 0.5 percentage points over the period (BLS, 1993).

There are several reasons that the JGF measures may be different from those of the BLS. As pointed out previously, the JGF method uses average wage rates across strata that differ by various key factors, i.e., education. These differences may also reflect other characteristics that are correlated with education. The BLS method corrects for these other differences and considers only the marginal effect of education. To estimate the effect of moving from the BLS to the JGF technique, we generate new JGF estimates using the BLS categories of Table 3.1 but the average wage rates appropriate to the JGF technique (Table 3.5, column 3). Each of the new estimates of the growth in labour services due to changes in labour composition is slightly higher than before.

The number of categories chosen might also be expected to make a difference in the calculations. The BLS method that is used here discriminates more finely with respect to age; the JGF method used here discriminates more finely by separating self from paid employment. The BLS approach has 480 categories in all, the JGF has 112. When we use the BLS method but JGF age-categories, the estimates decline slightly (Table 3.5, column 4).

Table 3.6 Average Annual Growth of Labour Composition in Canada and U.S.

	Annual Growth of Labour Composition (%)
JGF Method, the 1961-1995 Period	
Canada	0.63
United States*(Ho and Jorgenson, 1998)	0.51
BLS Method, the 1970-1990 Period	
Canada	0.38
United States (BLS, 1993)	0.27

* The labour composition estimate for the U.S. by Ho and Jorgenson (1998) is for the private sector that excludes the government but includes the employees of private households and nonprofit institutions. Labour composition for Canada is for the business sector.

The results of making both sets of changes—that is, using the data set that was employed for the BLS estimates, but using the JGF methodology, and the JGF age categories is presented in Table 3.5, column 5. Most of the gap between the two estimates is now accounted for.

The remaining differences are due to three factors. First, the hours and earnings used in the BLS and JGF calculations are not completely the same. After 1976, the JGF hours data are reconciled with the hours data from the LFS for each of the worker characteristics. The JGF hourly earnings data are reconciled with the hourly earnings data from the SCF and SLID. But this was not done for the BLS estimates. Second, the JGF approach treats the self-employed differently both by making them a separate category and in the way that their wage rate is calculated. The JGF technique assigns the average industry wage rate of the employed to the self-employed in the same industry. The BLS technique assigns the self-employed the same wage rate as paid employees of the same age and education class.

3.5. Comparison of Labour Compositional Changes between Canada and the U.S.

Methodological differences in the measurement of labour composition make international comparisons risky. Nevertheless, we present a comparison here to an estimate provided by Ho and Jorgenson (1998), who use the JGF method to estimate labour composition index for the U.S. private sector. Much like our study, they disaggregate hours worked by gender, age, education and class of workers. They also employ the same definition of the private business sector as is adopted here. Table 3.6 presents average annual growth rates of labour composition in the Canadian business sector and the U.S. private sector over the 1961-1995 period. Since 1961, the annual growth rate of labour composition has averaged 0.63% in Canada, compared with 0.51% in the United States.

Canada-U.S comparisons using a BLS-type method for a shorter period are provided in the bottom panel of Table 3.6. While the JFG estimates are quite similar in terms of methodology, there are more differences for the BLS methodology. The U.S. BLS method uses slightly different education levels and an estimate of experience on the job rather than age to create categories. Corresponding education categories and experience variables could not be created with the Canadian data. Nevertheless, the BLS-type results are of the same order of magnitude for both countries. As with the JGF estimates, Canada is about 0.10% higher than the United States.

Table 3.7 Average Annual Growth of Labour Productivity in the Business Sector (%)

Period	Output Per Hour (1)	Contribution from Labour Composition (2)	Output Per Unit of Labour Services (3)
1961-2000	1.98	0.42	1.36
Sub-periods			
1961-1973	3.67	0.57	2.83
1973-1979	1.44	0.06	1.35
1979-1988	1.06	0.39	0.47
1988-1995	1.23	0.62	0.33
1995-2000	1.70	0.30	1.39

3.6 Implication of Labour Compositional Changes for Labour Productivity Growth

Since labour services growth is higher when differences across worker categories are weighted by a proxy for their relative productivity, the resulting estimates of labour productivity and multifactor productivity will be lower. Existing measures that do not consider labour compositional change in effect do not consider the causes of output growth that arise from this compositional change—from increasing the share of hours worked accounted for by higher quality workers.

Labour compositional changes are an important source of labour productivity growth. The contribution of labour compositional changes to the growth of output per hour worked for the business sector using the JGF estimates developed earlier is presented in Table 3.7. Column 1 contains the annual productivity growth rate that is derived from using straight hours worked. Column 2 contains the contribution of the usual labour productivity measure that comes from changes in labour composition. The contribution of labour composition to the growth of output per hour equals the change in labour composition times the average share of labour compensation in value-added. Column 3 contains the increase in output per unit of labour services, where growth in labour services is calculated using the JGF method.

For the 1961-2000 period, labour compositional changes contributed 0.42 percentage points to the 1.98% annual growth of output per hour. In the period prior to 1973, labour compositional changes contributed 0.57 percentage points to the growth of output per hour. It then fell substantially in the subsequent two periods. The importance of labour composition for labour productivity growth increased in the 1988-1995 period. For that period, labour composition accounted for 0.62 percentage points of labour productivity growth. After 1995, 0.30 percentage points of the growth in output per hour came from changes in labour composition.

Without the correction, labour productivity grew over the period from 1961-2000 by 1.98% per year; after the correction, it grew by only 1.36%. For the business sector, taking the effect of labour composition into account narrows the gap in labour productivity growth between the 1961-1973 period and the 1973-1979 period, but not between the 1961-1973 period and the 1979-1988 period.

3.7 Conclusion

This chapter has examined the effect of relaxing the assumption that labour is homogeneous when estimating rates of growth of labour inputs. In doing so, it calculates an index of labour services that weights the rates of growth of hours worked in different groups of workers by their relative productivity (proxied by relative wage shares).

Two separate approaches were adopted. The first proxies relative productivity by average wages in a category. The second uses multivariate analysis to estimate the marginal effects of key characteristics like education and age along with other variables like marital status.

Using both approaches, we find that the weighted rate of growth of labour services—a measure that takes into account the differences in relative productivity of different worker categories—is higher than growth rates derived from the straight sum of hours worked—the traditional measure that has been used in Canadian estimates of productivity growth. This difference is defined as the compositional growth effect (sometimes referred to as the quality effect) and comes from differential rates of growth of hours worked across different labour types.

The fact that the compositional effect is positive means that output growth in Canada has partly arisen because hours-worked have been increasing faster in those worker groups that have higher productivity. Because of this, productivity estimates that are adjusted downward for labour compositional changes are lower than those based on the sum of hours worked across all worker categories.

The study finds that rising educational attainment explains almost all of the growth in labour compositional changes in Canada. The changes in the gender and age mix of the Canadian workforce have offsetting effects on labour composition growth.

We take from this several lessons for the productivity program.

The technique adopted here to correct for heterogeneity in labour services is based on the notion that relative wage rates approximate relative marginal productivity. It is this assumption that underlies much of the productivity literature. For example, estimates of multifactor productivity weight labour by labour's share of GDP and capital by capital's share. And in doing so, practitioners generally assume that they are doing so to capture the marginal productivity of each factor. Therefore, making such assumptions in using wage share weights in aggregating different types of labour is in keeping with the spirit of present practices. However, there is still the question as to how far this assumption should be pushed. Relative wages probably do not reflect relative productivity in all labour markets. Assuming that relative male/female wages fully reflect marginal productivity differences and not discrimination is a case in point.

The issue then is one of deciding which characteristics to take into account when making corrections for labour heterogeneity. Fortunately for this analysis, there is evidence to suggest that education is the most important factor empirically. Focusing on this and age as a proxy for experience is sufficient for practical purposes. Therefore, gender will not be used in the estimates that will be published.

There is still the issue of the methodology that should be pursued. There are substantial differences in the U.S. estimates produced by the JFG and the BLS approaches. Both yield quite similar estimates in Canada when the categories that are used for the analysis are harmonized and calculated using very similar databases. The estimate of labour compositional change in Canada is not very sensitive to which of the two types of estimation approaches are adopted.

One of the major advantages of the BLS method is that it uses an imputed experience variable rather than age to capture the advantages that older workers gain from experience. But since a good estimate of actual work experience is not available for Canada, the BLS method loses some of the potential advantage over the JGF method. Moreover, an experimentation of wage regressions from various household surveys (SCF) shows year-over-year variations in the estimated coefficients on education and age variables, especially at industry levels which introduces measurement errors in the BLS-type method. Finally, we also find that the JGF method is computationally much simpler for Canada than the BLS method. Since the JGF and BLS results are quite similar, the JGF method will be adopted for calculating changes in Canadian labour composition.

Finally, a caveat is in order for those who will use the new estimates of labour productivity that take into account changes in the quality of labour. The fact that education is so important raises a separate issue as to how the new productivity estimates should be interpreted. To simply say that productivity growth is lower than some might otherwise have thought is misleading. It is lower in the business sector. But this improvement has come from improved output levels of the education sector, which are not included in the business sector productivity estimates. These improvements should be attributed to the public sector. Total productivity gains are not reduced. They are simply reallocated.

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Appendix Table 3.A1 Annual Average Growth of Labour Productivity and Labour Composition by Industry, 1961-1997, Using the JGF Method (%)

Industry	Value-added Per Hour	Value-added Per Unit of Labour	Labour Composition
1 Agricultural and Related Service	3.74	3.09	0.65
2 Fishing and Trapping	-0.04	-0.58	0.54
3 Logging and Forestry	2.25	1.77	0.48
4 Gold Mines	1.32	0.53	0.79
5 Other Metal Mines	1.13	0.66	0.48
6 Iron Mines	3.49	3.01	0.47
7 Asbestos Mines	-0.33	-0.79	0.46
8 Other Non-metal Mines (except coal)	5.59	4.94	0.65
9 Salt Mines	4.95	4.46	0.49
10 Coal Mines	6.28	5.68	0.60
11 Crude Petroleum and Natural Gas	-1.42	-1.93	0.51
12 Quarry and Sand Pit Industries	3.34	2.87	0.46
13 Service Industries Incidental to Mineral Extraction	0.20	-0.33	0.53
14 Meat and Meat Products (except poultry)	0.18	-0.07	0.24
15 Poultry Products	0.34	-0.30	0.64
16 Fish Products	0.06	-0.36	0.42
17 Fruit and Vegetables	3.89	3.36	0.53
18 Dairy Products	1.98	1.45	0.53
19 Miscellaneous Food Products	2.07	1.41	0.66
20 Feed	4.73	4.09	0.64
21 Vegetable Oil Mills (except corn oil)	5.90	4.30	1.61
22 Biscuit	0.90	-0.07	0.97
23 Bread and Pther Bakery Products	1.09	0.46	0.63
24 Cane and Beet Sugar	1.65	1.25	0.40
25 Soft Drink	2.15	1.26	0.90
26 Distillery Products	3.39	2.33	1.06
27 Brewery Products	1.61	0.98	0.63
28 Wine	4.21	3.62	0.59
29 Tobacco Products	3.52	2.59	0.93
30 Rubber Products	3.92	3.44	0.47
31 Plastic Products	4.12	3.55	0.57
32 Leather Tanneries	1.83	1.56	0.27
33 Footwear	1.81	1.39	0.42
34 Miscellaneous Leather and Allied Products	2.49	2.03	0.47
35 Man-made Fibre Yarn and Woven Cloth	6.17	4.95	1.22
36 Wool Yarn and Woven Cloth	2.26	1.46	0.80
37 Broad Knitted Fabric	9.68	8.49	1.19
38 Miscellaneous Textile Products	2.79	2.21	0.58
39 Carpet, Mat and Rug	6.84	6.02	0.82
40 Clothing Industries Excluding Hosiery	2.59	2.32	0.27
41 Hosiery	6.01	5.71	0.30
42 Sawmill, Planing Mill and Shingle Mill Product	3.09	2.38	0.70
43 Veneer and Plywood	2.39	1.86	0.53
44 Sash, Door and Other Millwork	0.98	0.55	0.43
45 Wooden Box and Coffin	0.46	-0.15	0.61
46 Other Wood	2.02	1.36	0.66
47 Household Furniture	0.82	0.55	0.28
48 Office Furniture	2.35	0.85	1.50
49 Other Furniture and Fixtures	2.15	1.45	0.70
50 Pulp and Paper	2.17	1.64	0.53
51 Asphalt Roofing	4.39	3.40	0.99
52 Paper Box and Bag	2.16	1.42	0.73
53 Other Converted Paper Products	2.65	1.98	0.67
54 Printing and Publishing	0.37	0.07	0.30
55 Platemaking, Typesetting and Bindery	0.93	0.80	0.12
56 Primary Steel	2.13	1.60	0.54
57 Steel Pipe and Tube	5.63	5.17	0.46
58 Iron Foundries	2.77	2.23	0.54
59 Non-ferrous Metal Smelting and Refining	2.89	2.35	0.54

Appendix Table 3.A1 Annual Average Growth of Labour Productivity and Labour Composition by Industry, 1961-1997, Using the JGF Method (%) – *continued*

	Industry	Value-added Per Hour	Value-added Per Unit of Labour	Labour Composition
60	Aluminum rolling, Casting and Extruding	3.53	2.95	0.58
61	Copper and Alloy Rolling, Casting and Extruding	1.64	1.12	0.52
62	Other Rolling, Casting and Extruding Non-ferrous Metal Products	-0.34	-0.79	0.46
63	Power Boiler and Structural Metal	1.05	0.55	0.50
64	Ornamental and Architectural Metal Products	2.84	2.41	0.43
65	Stamped, Pressed and Coated Metal Products	1.32	0.80	0.52
66	Wire and Wire Products	1.76	1.22	0.54
67	Hardware, Tool and Cutlery	1.00	0.45	0.55
68	Heating Equipment	2.30	1.58	0.72
69	Machine Shop	1.90	1.27	0.63
70	Other Metal Fabricating	1.96	1.48	0.48
71	Agricultural Implement	3.07	2.77	0.31
72	Commercial Refrigeration and Air Conditioning Equipment	4.51	3.72	0.79
73	Other Machinery and Equipment	1.48	1.00	0.49
74	Aircraft and Aircraft Parts	1.53	1.02	0.51
75	Motor Vehicle	6.06	5.69	0.37
76	Truck and Bus Body and Trailer	3.48	3.11	0.37
77	Motor Vehicle Parts and Accessories	4.56	4.12	0.44
78	Railroad Rolling Stock	1.05	0.52	0.53
79	Shipbuilding and Repair	1.63	1.06	0.57
80	Miscellaneous Transportation Equipment	5.12	4.09	1.03
81	Small Electrical Appliance	4.54	4.16	0.38
82	Major Appliance (electric and non-electric)	4.85	4.35	0.50
83	Other Electrical and Electronic Products	2.75	2.04	0.72
84	Record Player, Radio and t.v. Receiver	4.70	4.24	0.46
85	Communication and Other Electronic Equipment	4.61	4.00	0.61
86	Office, Store and Business Machines	13.96	13.30	0.67
87	Communication and Energy Wire and Cable	2.32	1.78	0.54
88	Battery	2.43	1.94	0.49
89	Clay Products	1.62	1.94	-0.32
90	Hydraulic Cement	1.56	0.96	0.60
91	Concrete Products	1.38	0.77	0.61
92	Ready-mix Concrete	1.66	1.27	0.38
93	Glass and Glass Products	3.59	3.24	0.35
94	Miscellaneous Non-metallic Mineral Product	2.77	2.12	0.65
95	Refined Petroleum and Coal Products	4.47	3.84	0.63
96	Industrial Chemicals n.e.c.	5.29	4.66	0.64
97	Chemical Products n.e.c.	3.54	2.90	0.64
98	Plastic and Synthetic Resin	5.62	4.89	0.73
99	Pharmaceutical and Medicine	4.71	4.16	0.55
100	Paint and Varnish	0.88	0.42	0.46
101	Soap and Cleaning Compounds	3.56	3.06	0.49
102	Toilet Preparations	1.96	0.80	1.17
103	Other Manufacturing	2.60	2.07	0.53
104	Jewellery and Precious Metals	-0.45	-0.59	0.14
105	Sporting Goods and Toys	3.22	2.77	0.45
106	Sign and Display	0.31	0.32	-0.01
108-116	Construction	0.94	0.43	0.51
117	Air Transport and Related Service	0.78	0.20	0.58
118	Railway Transport and Related Service	7.11	6.61	0.49
119	Water Transport and Related Services	3.06	2.60	0.46
120	Truck Transport	2.41	1.98	0.44
121	Urban Transit Systems	-2.16	-2.40	0.24
122	Interurban and Rural Transit Systems	0.13	-0.32	0.45
123	Miscellaneous Transport Services	0.15	-0.28	0.43
124	Pipeline Transport	2.38	1.77	0.62
125	Storage and Warehousing	1.77	1.38	0.39
126	Telecommunication Broadcasting	2.22	1.72	0.50
127	Telecommunication Carriers	5.88	5.22	0.66

Appendix Table 3.A1 Annual Average Growth of Labour Productivity and Labour Composition by Industry, 1961-1997, Using the JGF Method (%) – *concluded*

Industry		Value-added Per Hour	Value-added Per Unit of Labour	Labour Composition
128	Postal and Courier Service	0.65	0.42	0.22
129	Electric Power Systems	2.48	1.77	0.70
130	Gas Distribution Systems	2.87	2.37	0.50
131	Water Systems and Other Utility n.e.c.	2.59	2.09	0.50
132	Wholesale Trade	2.39	1.94	0.44
133	Retail Trade	1.97	1.65	0.32
134	Finance and Real Estate	-0.35	-0.85	0.49
135	Insurance	2.03	1.68	0.35
137	Other Business Services	2.44	1.43	1.01
138	Professional Business Services	-0.27	-0.60	0.34
139	Advertising Services	-1.46	-1.28	-0.19
140	Educational Service	-0.36	-0.92	0.56
141	Other Health and Social Service	-1.03	0.29	-1.32
142	Accommodation and Food Services	-0.21	-0.68	0.47
143	Motion Picture and Video	-0.62	-0.60	-0.02
144	Other Amusement and Recreational Services	-0.07	-0.76	0.69
145	Other Personal Service	0.05	-0.39	0.44
146	Laundries and Cleaners	0.37	0.13	0.24
147	Membership Organizations (excluding religions) and Other Services	1.24	1.02	0.22

Appendix Table 3.A2 Women's Log Wage Rate Regressions Using Canadian Census Data (Private Industry Employees or Incorporated Self-employed)

Independent Variable	Coefficient Values for Census Years:				
	1971	1981	1986	1991	1996
Intercept	0.267	0.699	0.681	0.969	0.956
Age	0.023	0.040	0.054	0.050	0.050
Age-squared	-0.00026	-0.00044	-0.00057	-0.00053	-0.00048
Elementary school	-0.146	-0.169	-0.217	-0.223	-0.214
Post-secondary	0.088	0.088	0.066	0.122	0.127
Degree	0.330	0.319	0.295	0.385	0.392
Now-married	0.078	0.069	0.092	0.055	0.085
Immigrated Within 6 Years	-0.137	-0.243	-0.289	-0.270	-0.346
Immigrated Earlier	-0.025	-0.044	-0.052	-0.044	-0.084
Different Home Language	-0.006	-0.037	-0.045	-0.089	-0.111
Currently Part-time	-0.533	-0.071	-0.126	-0.092	-0.110
In Large City (>100,000)	0.136	0.109	0.125	0.156	0.134
Full-time this Year and Last	-0.183	-0.029	-0.005	-0.090	-0.064
Has One Child	-0.023	-0.028	-0.027	-0.023	-0.004
Has 2 or 3 Children	-0.052	-0.033	-0.020	-0.020	0.022
Has 4 or More Children	-0.103	-0.103	-0.082	-0.099	-0.008
Prince Edward Island	-0.064	-0.031	-0.053	-0.031	*0.009
Nova Scotia	*-0.005	-0.025	-0.034	-0.017	0.024
New Brunswick	0.065	0.033	0.028	0.040	0.067
Quebec	0.206	0.146	0.091	0.135	0.199
Ontario	0.236	0.115	0.096	0.233	0.311
Manitoba	0.087	0.041	0.017	0.019	0.077
Saskatchewan	0.022	0.117	0.068	-0.058	0.060
Alberta	0.171	0.221	0.163	0.137	0.202
British Columbia	0.267	0.284	0.177	0.212	0.349
Yukon, Northwest Territories and Nunavit	0.422	0.356	0.316	0.362	0.439
Manufacturing	0.110	0.113	0.161	0.208	0.128
Communication/Transport/Energy	0.200	0.246	0.332	0.332	0.261
Financial and Banking Services	0.078	0.163	0.220	0.262	0.212
Commercial Services	-0.047	-0.014	0.022	0.064	-0.007
Number of Observations	606,190	417,194	534,570	542,030	586,776
R-squared	0.297	0.198	0.300	0.247	0.286

* Statistically not significant

Note: omitted category of multiple categories: some high school, primary industries, Newfoundland.

Appendix Table 3.A3 Men's Log wage Rate Regressions Using Canadian Census Data (Private Industry Employees or Incorporated Self-employed)

Independent Variable	Coefficient Values for Census Years:				
	1971	1981	1986	1991	1996
Intercept	0.168	0.745	0.689	1.126	1.165
Age	0.053	0.057	0.069	0.061	0.059
Age-squared	-0.00055	-0.00059	-0.00070	-0.00060	-0.00055
Elementary School	-0.143	-0.159	-0.172	-0.180	-0.172
Post-secondary	0.111	0.082	0.069	0.106	0.109
Degree	0.431	0.351	0.335	0.383	0.387
Now-married	0.180	0.154	0.154	0.135	0.118
Immigrated Within 6 Years	-0.154	-0.245	-0.312	-0.347	-0.395
Immigrated Earlier	-0.036	-0.064	-0.062	-0.068	-0.101
Different Home Language	-0.027	-0.056	-0.070	-0.107	-0.133
Currently Part-time	-0.314	-0.218	-0.245	-0.224	-0.242
In Large City (>100,000)	0.085	0.076	0.089	0.097	0.071
Full-time this Year & Last	-0.164	-0.079	-0.024	-0.106	-0.046
Has One Child	0.008	0.010	-0.013	-0.001*	0.001
Has 2 or 3 Children	0.076	0.050	0.025	0.038	0.035
Has 4 or More Children	0.070	-0.040	-0.038	-0.059	-0.077
Prince Edward Island	-0.262	-0.177	-0.155	-0.158	-0.163
Nova Scotia	-0.073	-0.067	-0.026	-0.040	-0.091
New Brunswick	-0.035	0.014	0.039	0.038	-0.002
Province of Quebec	0.099	0.084	0.085	0.088	0.067
Ontario	0.153	0.099	0.113	0.176	0.150
Manitoba	0.022	0.004	-0.009	-0.057	-0.061
Saskatchewan	-0.030	0.062	0.021	-0.083	-0.052
Alberta	0.108	0.209	0.162	0.080	0.080
British Columbia	0.200	0.248	0.188	0.168	0.191
Yukon, Northwest Territories and Nunavit	0.296	0.218	0.233	0.246	0.229
Manufacturing	0.035	0.085	0.116	0.113	0.096
Communication/Transport/Energy	0.023	0.092	0.141	0.118	0.075
Financial and Banking Services	0.029	0.114	0.128	0.126	0.206
Commercial Services	-0.087	-0.082	-0.069	-0.048	-0.084
Number of Observations	1,337,216	804,416	895,317	871,912	929,023
R-squared	0.390	0.375	0.462	0.368	0.391

* Statistically not significant

Note: omitted category of multiple categories: some high school, primary industries, Newfoundland

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4

A Comprehensive Revision of the Capital Input Methodology for Statistics Canada's Multifactor Productivity Program

Tarek M. Harchaoui and Faouzi Tarkhani

4.1. Introduction

Measuring economic performance involves comparisons in terms of output, inputs (capital, labour and intermediate inputs) or productivity measures across industries and over different time periods. The productivity accounts have provided a useful framework for organizing the information required for comparisons of this type. Productivity accounts decompose rates of change in output into the portions that arise from increases in various inputs and a residual that is defined as multifactor productivity. This factor encompasses technical change, organizational change and all other factors that are not subsumed in the input growth measures.

Comparisons of productivity performance across industries or countries are of great interest from an academic point of view. They are also of interest from the public policy perspective. Evaluation of alternative policies involves comparison of the present state of affairs and possible alternative states associated with changes in policy.

Until 1987, productivity figures produced by Statistics Canada were expressed in terms of output per employee—a simple measure of labour productivity. In the early 1990s, Statistics Canada introduced a better measure of labour input that makes use of the number of hours worked. The measure of labour productivity growth reflects not only changes in technology but also changes in the availability of capital per hour—a result of capital accumulation rather than of improved labour efficiency.

For this reason, Statistics Canada followed the advice of professional economists and developed the multifactor productivity program to better measure the efficiency with which several inputs are jointly used. Multifactor productivity growth measures the increase in output that is achieved beyond the increase in all inputs—both capital and labour. It can arise from outward shifts in the aggregate production function brought about by technological change, and, under certain conditions, the latter can be measured by changes in the multifactor productivity measure alone. When these conditions do not hold, alternative methods are used to separate out the technological shift component from other factors like the exploitation of scale economies that are at work.[1]

Multifactor productivity measurement involves comparing changes in output with changes in inputs. The microeconomic theory of the firm uses a 'production function' to formally describe the relationship between the services of inputs and output. Capital is, of course, one type of input. However, capital goods do not neatly conform with the

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[1] See Baldwin, Gaudreault and Harchaoui (2001) for an illustration of the parametric approach to productivity measurement.

simple production model. Among other things, they are not consumed in production. Nonetheless, capital goods must specifically be deployed in production for a period of time in order to *render services.* A measure of capital input which would be consistent with production theory is therefore the quantity of the *flow of services* provided by capital goods.

Because many different types of capital goods are used in production, an aggregate measure of the capital stock or of capital services must be constructed. For net stocks used in the *wealth* accounts this is a straightforward matter of summing estimates for different types of assets. In so doing, market prices serve as aggregation weights. The situation is different for the capital services estimates needed for *productivity* analysis. Typically, each type of asset is associated with a specific flow of capital services and strict proportionality is assumed between capital services and capital stocks at the level of individual assets. This ratio may not be the same, however, for different kinds of assets, so that the aggregate stock derived from the wealth accounts and the flows covering different kinds of assets needed for productivity analysis may diverge. A single measure of capital stock cannot serve both purposes except when there is only one single homogenous capital good.

To better understand why this is the case, consider the process by which multifactor productivity is estimated. Multifactor productivity is defined as the difference between growth in output Q and the contributions that capital K and labour L make to the growth in output as a result of the use of additional units of capital and labour—$C(\Delta K)$ and $C(\Delta L)$, respectively.

$$MFP = \Delta Q - C(\Delta K) - C(\Delta L)$$

The contribution that labour or capital make to output growth is just the marginal product of labour (capital) multiplied by the change in labour (capital) devoted to production. If the production function is characterized by constant returns to scale and prices of inputs (labour and capital) equal to their marginal revenue product, then the share of labour in total output (s_L) or the share of capital in total product (s_K) may be taken as representing the marginal product of each factor.

Thus

$$MFP = \Delta Q - s_K(\Delta K) - s_L(\Delta L)\,.$$

In a world where all assets have the same marginal product, changes in capital may be estimated by simply summing the value of all assets and calculating changes therein over time. But if there are n assets, each with a different marginal product of capital s_{K_i}, then the appropriate formulae for estimating the effect of capital is

$$C(\Delta K) = s_{K_1}\Delta K_1 + s_{K_2}\Delta K_2 + .. + s_{K_n}\Delta K_n\,,$$

where s_{K_a} can be approximated by the share of total output that goes to each type of capital a $(a = 1, 2, \ldots n)$.

The appropriate weights then to estimate changes in capital stock are the relative shares of each asset in total capital compensation. In order to estimate these shares, we need to calculate the unit price of each type of asset $\left(c_a\right)$—since the share of each asset in total capital costs is just

$$s_{K_1} = \frac{c_1 K_1}{\sum_a c_a K_a} .$$

A simple measure of capital stock may not be the appropriate measure of capital for an aggregate production function analysis when there is a wide array of heterogeneous assets that have different productive characteristics. Only if asset prices are the same will it be possible to simply sum the dollar values of all assets and aggregate them. In this chapter, we discuss the methodology that has been employed to estimate the various asset prices c_a of different assets a.[2]

To address this measurement problem, Griliches and Jorgenson (1966) and Jorgenson and Griliches (1967) introduced "constant quality" indices of capital services, also called capital input, which recognize that tangible assets, purchased for the same number of dollars, have different service lives, depreciation rates, tax treatments, and ultimately different marginal products.

Constant quality indexes of capital services use an asset-specific "user cost of capital," as derived by Jorgenson (1963) and further developed in Hall and Jorgenson (1967), to aggregate heterogeneous capital assets. This user cost approach has important advantages over the simpler capital stock approach, which uses acquisition prices to weight different assets. Weighting assets by their user cost, which equals the marginal product in a competitive equilibrium, effectively incorporates differences in the productive contribution of heterogeneous investments as the composition of investment and capital changes. In this case, changes in aggregate capital input have two distinct components—changes in the quantity of capital of a given type, and changes in the composition of the various types of assets with different marginal products and user costs. This second effect—arising from the change in the importance of different capital types in the aggregate capital stock—is sometimes referred to as the change in the "quality" of capital services or the compositional effect of changing the nature of the bundle of assets. It explicitly captures substitution between heterogeneous assets in response to changing relative prices of different assets.

While Jorgenson's pioneering efforts have provided the broad outlines of the framework needed to overcome the lack of directly observable and measurable prices of capital services, providing a link between the model's theoretical structure and its application has been more difficult. In particular, there is a considerable difference between the rental price as a theoretical paradigm and its real world empirical application. This chapter discusses some of the issues that have to be resolved in order to bridge this gap.

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[2] The same issue is relevant when it comes to estimating the change in hours-worked and is discussed in chapter 3 of this volume.

Accordingly, the primary purpose of this paper is to present a systematic discussion of the conceptual and measurement issues related to measuring the set of rental price components. The issues developed here are of fundamental importance in the measurement of capital input used by the multifactor productivity framework. The manner in which the user cost of capital components are measured makes them particularly vulnerable to error-in-variable problems. Unfortunately, there has been both little discussion of the concepts behind the components of the rental price and little testing of the impact of alternative measures of these components on the quality of capital input estimates (see Diewert and Lawrence 1999; Bernstein 2000).

We first review the guidance provided by economic theory in discriminating among alternative rental price formulae employed in the empirical literature. This results in a set of five possible rental price measures that we then evaluate in the context of the multifactor productivity growth accounting framework. The empirical evaluation procedure is based on a comparison of the five alternative rental price estimates using a common data set covering 122 industries (1980 SIC) of the Canadian business sector over the 1961-2000 time period, with 28 distinct types of capital assets.

The chapter is organized as follows. Section 4.2 provides a comprehensive summary of the concept of capital services and its underlying assumptions. Section 4.3 discusses the domain of definition of capital stock and the aggregation techniques required for the construction of capital input estimates. Section 4.4 develops, at length, the concepts and practical considerations that underlie the cost of capital measure. Section 4.5 analyzes the estimates of the user cost of capital and the capital assets. This section also evaluates the effect of alternate measures of the user cost on the growth of capital composition. Concluding remarks are drawn in Section 4.6 on the role of capital in the Canadian business sector's economic growth and a comparison of Canada-U.S. productivity performance. Appendix 4.A describes the sources of the tax variables used in the construction of the user cost of capital estimates. Appendix 4.B provides a formal description of the procedures used to arrive at the concept of aggregate capital services.

4.1.1 Capital in the Productivity Literature

This section provides a detailed summary of the methodology used to calculate capital services. Starting with investment data, we calculate capital stocks using the perpetual inventory method, and then estimate the user cost of capital for each asset from tax records and national accounts data.

These stocks are then aggregated using the user cost of capital to weight individual assets to form an estimate of the flow of capital services. A reader not interested in the nuances of capital theory and measurement can skip this section for our empirical results in Sections 4.4 and 4.5.

Our objective is to construct a measure of aggregate capital services that can account for the heterogeneity in investment goods and the changing composition of the Canadian capital stock, yet also remain tractable. This tractability issue raises important conceptual issues about the fundamental nature of capital. One could argue that each piece of capital is distinct and must be included separately in a production function, i.e., automobiles are not perfect substitutes for tractors or a personal computer with a 486 chip is not a substitute for one with a Pentium-Pro chip. While desirable, such an approach is obviously impossible to implement given the large number of assets involved.[3]

Therefore, our model of production assumes output is a function of aggregate capital services, $\tilde{K}_t$ where $\tilde{K}_t = f\,(K_{1t}, K_{2t}, ..., K_{At}\,)$ is an aggregate of services from A heterogeneous assets. Moreover, these services are separable from other inputs like labour $L_t = f\,(L_{1t}, L_{2t}, ..., L_{Tt}\,)$, and K_{at} itself is an average of individual items, e.g., the 'aircraft' asset includes many different types, models, and vintages. The user cost of asset a, c_{at}, represents the average rental cost per effective unit of "aircraft." Using these rental prices, which equal the marginal product of capital in competitive equilibrium, the many heterogeneous $\tilde{K}_{at}$'s can be aggregated into a single index of capital services, $\tilde{K}_t$.

4.2 The Concepts: Stocks and Flows

Investment involves the acquisition of capital goods at a given point in time. The quantity of investment is measured in the same way as the durable goods themselves.[4] For example, investment in equipment is the number of machines of a given specification and investment in buildings is the number of buildings of a particular description. The price of acquisition of a durable good is the unit cost of acquiring a piece of equipment or a structure.

In contrast to investment, capital services are measured in terms of the use of a durable good *for a stipulated period of time*. For example, a building can be leased for a period of years, an automobile can be rented for a number of days or weeks, and computer time can purchased in seconds or minutes. The price of the services of a durable good is the unit cost of using the good for a specified period.

In the durable goods model of production, capital input plays a role that is analogous to that of any other input. But the distinguishing feature of capital is that durable goods provide services at different points of time. The capital services provided by a given durable good at a point in time are proportional to the initial investment. Durable goods acquired at different points of time are usually referred to as different vintages of capital.

The flow of capital services then needs to be constructed as a quantity index of capital inputs from durable goods of different vintages. The flow of capital services from a set of durable goods of different vintages is a weighted sum of past investments. The weights correspond to the relative efficiencies of the different vintages of capital.

The relative efficiency of a capital good is assumed to depend on the age of the good and not on the time it is acquired. Replacement requirements are determined by losses in efficiency of existing capital goods as well as by actual physical retirement of capital goods. When a capital good is retired, its relative efficiency drops to zero. The relative

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[3] A parallel problem arises in the modelling of labour input where each worker is different, but some averaging is necessary to construct tractable measures of labour. See Ho and Jorgenson (1999) for example.

[4] This section relies on Jorgenson (1995, pp. 28-45)

efficiencies of capital goods of different ages can be described by a sequence of non-negative numbers $d_o, d_1, \ldots$, the relative efficiency of a new capital good is normalized at unity, and the relative efficiency is assumed non-increasing, so that: $d_0 = 1$ and $d_\tau - d_{\tau-1} \geq 0 \quad (\tau = 0,1,\ldots)$. It is also assumed that every capital good is eventually retired or scrapped so that relative efficiency eventually drops to zero, that is $\underset{\tau\to\infty}{\ell im}\, d_\tau = 0$.

As an illustration of patterns in the decline in relative efficiency, we can consider the declining balance pattern, where efficiency is assumed to decline geometrically $d_\tau = (1-\delta)^\tau \quad (\tau = 0,1,\ldots)$.[5]

To characterize capital as a factor of production, consider the following production function that is homothetically separable in the services of different vintages of capital

$$Y_t = F\left(f\left(K_{t,0}, K_{t,1}, \ldots, K_{t,\tau}, \ldots\right), L_t, M_t, t\right),$$

where the function F is homogeneous of degree one in the services from capital goods of different ages. If we assume that the quantity index of capital input K_t is characterized by perfect substitutability among the services of different vintages of capital, we can write this index as the sum of these capital services

$$K_t = \sum_{\tau=0}^{\infty} K_{t,\tau} .$$

Under the additional assumption that the services provided by a durable capital good are proportional to initial investment in this good, we can express the quantity index of capital input in the form

$$K_t = \sum_{\tau=0}^{\infty} d_\tau I_{t-\tau} . \tag{1}$$

The flow of capital services is a weighted sum of past investments with weights given by the relative efficiencies $\{d_\tau\}$ of capital goods of different ages.

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[5] There are two other patterns of decline in efficiency in the durable goods model of production that are often studied. In the one-hoss shay pattern, efficiency is constant over the life-time of the capital good. Where T is the lifetime, relative efficiency is is given by

$$d_\tau = \begin{cases} 1 & (\tau = 0,1,\ldots,T-1) \\ 0 & \text{otherwise.} \end{cases}$$

In the straight-line pattern, efficiency declines linearly over the lifetime of the capital good

$$d_\tau = \begin{cases} 1-\dfrac{\tau}{T} & (\tau = 0,1,\ldots,T-1) \\ 0 & \text{otherwise.} \end{cases}$$

Capital goods decline in efficiency at each point of time, giving rise to needs for a replacement if productive capacity is to be maintained. Taking the first difference of the expression for capital stock in terms of past investments and assuming a geometric declining pattern for d_τ, we obtain

$$\begin{aligned} K_t - K_{t-1} &= I_t - \delta \sum\nolimits_{\tau=1}^{\infty} (1-\delta)^{\tau-1} I_{t-\tau} \\ &= I_t - \delta K_{t-1}, \end{aligned} \tag{2}$$

which is the perpetual inventory formulation of capital stock.

4.2.2 A Dual Interpretation of the Capital Concept

In the durable goods model of production, the price counterpart of capital stock, K_t, is the acquisition price of investment goods, q_t. The rental prices of capital goods of different ages are proportional to the rental price of a new capital good. The constants of proportionality are the relative efficiencies $(1-\delta)^\tau$. The acquisition price of investment goods q_t is the sum of future rental prices of capital services c_t, weighted by the relative efficiencies of capital goods in each future period, $(1-\delta)^\tau$, and discounted to the present.

$$q_t = \sum\nolimits_{\tau=0}^{\infty} (1-\delta)^{\tau} \prod_{s=1}^{\tau+1} \frac{1}{(1+r_{s+t})} c_{t+\tau+1},$$

where r_{s+t} is the rate of return in period $s+t$. In a competitive market for capital goods, ignoring taxes and uncertainty, the price of the asset will equal the discounted sum of the future rental prices from the depreciating asset.

The acquisition price of a durable good declines with the age of the good because of depreciation. Depreciation reflects both the current decline in efficiency and the present value of future declines in efficiency.

Assuming that the price reflects the expected future value of services and taking the first difference of the expression for the acquisition price of investment goods in terms of future rental, we obtain

$$q_t - q_{t-1} = -\frac{1}{(1+r_t)} c_t + \frac{(r_t+\delta)}{(1+r_t)} \sum\nolimits_{\tau=0}^{\infty} (1-\delta)^{\tau} \prod_{s=1}^{\tau+1} \frac{1}{(1+r_{s+t})} c_{t+\tau+1},$$

and the rental price of capital services is given by

$$c_t = q_{t-1}(r_t+\delta) - (q_t - q_{t-1}). \tag{3}$$

The cost of capital is an annualization factor that transforms the acquisition price of investment goods into the price of capital input.

The durable goods model of production is characterized by price-quantity duality. In this duality, the capital stock K_t corresponds to the sum of the acquisition price of all investment goods, q_t. Capital stock is a weighted sum of past investments, while the acquisition price of investment goods is a weighted sum of future rentals. Capital input in any one period is the service flow from the capital stock available at the beginning of the period. The price of capital input is the rental price of capital services for that period.

In the definition of capital stock, the weights on past investments correspond to relative efficiencies of capital goods of different ages. These weights are also applied to future rental prices in defining the acquisition price of investment goods. Replacement requirements are generated by the decline in efficiency of a capital good with age. Depreciation results from the decline in the price of acquisition of a capital good with age. A special feature of geometrically declining relative efficiencies is that the rate of replacement and the rate of depreciation are equal to the rate of decline in efficiency δ.

4.2.3 An Heuristic Interpretation of the User Cost of Capital

When a firm purchases a durable capital input, it is not appropriate to allocate the entire purchase price q_t as a cost to the initial period when the asset was purchased. It is necessary to distribute this initial purchase (the price of the asset) across the useful life of the asset. The concept of user cost of capital c_t does just that. It represents the amount of rent that would have been charged in order to cover costs of q dollars' worth an asset.

In equation (3), the user cost of capital of an asset c_t is the per-period cost of using the services of the asset. The first term of the user cost expression $q_{t-1}(r_t + \delta)$ measures the cost of financing the asset ($q_{t-1}r_t$). This is the interest payment if a loan was taken out to acquire the asset or the opportunity cost of employing capital elsewhere than in production if the acquisition of the asset was financed from external sources. Added to the interest cost is $q_{t-1}\delta$, the cost of depreciation or the loss in value of the machine because it ages. The loss in value reflects physical decay or efficiency loss of the asset, but also the fact that its expected service life has declined by one period.

Thus, two assets may have the same value, e.g., $P_{a,t}K_{a,t} = P_{k,t}K_{k,t}$, but they may have very different rental prices. For example, if the depreciation rate of a is faster than k, then rental payments will be larger for a than for k, $c_{a,t}K_{a,t} > c_{k,t}K_{k,t}$ (ignoring differences in the tax treatment). Intuitively, if the acquisition prices are the same, a short-lived asset must provide a larger rental value per dollar to balance out the faster depreciation.

It should be noted that the formula (3) abstracts from all effects of taxation. In his later contributions, Jorgenson augments the user cost expression to incorporate the effects of corporate income taxes, tax depreciation allowances, investment tax credits and indirect taxes. It is apparent that the inclusion of tax variables comes at a non-negligible cost. For a full implementation, historical and current tax laws have to be monitored, by type of asset and by industry, along with assumptions of assets' tax lives and estimates of business income tax rates (see Appendix 4.A at the end of this chapter).

To take into account taxes, Christensen and Jorgenson (1969) developed the following user cost formula c_{iat} for the a-th capital asset type, the i-th industry and period t

$$c_{iat} = q_{iat-1}\left\{\left(\frac{1-u_{it}z_{iat}-k_{iat}}{1-u_{it}}\right)\left[r_t+\delta_{ia}-\frac{(q^*_{iat}-q_{iat-1})}{q_{iat-1}}\right]+\phi_{it}\right\} \tag{4}$$

where ϕ_{it} is the effective rate of property taxes (nominal valued taxes assessed on the real stocks of land and structures, and $(\frac{1-uz-k}{1-u})$ is the effective rate of taxation on capital income, where u_{it} is the corporate income tax rate, z_{iat} is the present value of depreciation deductions for tax purposes on a dollar's investment in capital type a over the lifetime of the investment, and k_{iat} is the rate of the investment tax credit; $\frac{(q^*_{iat}-q_{iat-1})}{q_{iat-1}}$ is the expected capital gain (the remaining variables have already been defined above).

4.3 Construction of Capital Input

We usually cannot obtain direct measures of the prices or quantities of capital service flows. However, one important type of data, which relates directly to the 'shadow' market, is readily available: *property income*, defined as nominal revenues minus expenses for variable inputs (labour and purchased materials and services). Measures of property income for firms are readily available from accounting records. Data on property income by industry commonly are compiled as part of Input-Output Tables. In practice, property income includes depreciation allowances, interest and taxes.[6]

The measurement of the growth rate of capital services requires us to separate the growth rate of property income into components of quantity and price change. To do so, we construct detailed historical data on stock of assets K_{iat} by industry i, asset a and time period t to provide quantities using investment series and estimates of δ, depreciation (See Chapter 2 in this volume). On the price side, we estimate 'implicit rental prices' for detailed types of capital c_{iat}, so that the value of capital services $\sum_a c_{iat}K_{iat} \equiv \tilde{K}_{it}$ is equal to property income R_{it}. By substituting in equation (4) above for c_{iat}, and substituting known values for all variables except r_t, that is, depreciation, δ, tax rates, $(\frac{1-uz-k}{1-u})$, and capital gains, $\frac{(q^*_{iat}-q_{iat-1})}{q_{iat-1}}$ etc., the remaining variable r_t can be derived. Then, substituting r_t, the depreciation δ and the capital gains, $(q_t - q_{t-1})$, into the formula for c_{iat}, i.e., $c_t = q_{t-1}(r_t+\delta)-(q_t-q_{t-1})$ allows c, the rental price of capital, to be calculated.

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[6] See Harchaoui, et al. (2001, pp. 155-158) for a description on the various transformations that the productivity program implements on the data from Input-Output Tables.

We construct stocks and rental prices using as much asset detail as possible. Rental prices are then used in creating weights for aggregation of the various asset-type capital stocks. Index number theory is then used to aggregate these stocks in a capital input measure. These issues will be examined in detail in Appendix 4.B.

4.3.1 The Domain of Definition of Capital

In its broadest sense, capital includes anything that involves foregoing 'something' in the present to earn returns in the future. It can include reproducible equipment and structures, land, inventories, financial assets such as stocks and bonds, 'human capital' acquired through education, training or experience, and finally intangibles such as software development costs, advertising expenses, or organizational efforts. Diewert (1980b, pp. 265-266) provides a discussion of the 'domain of definition of capital':

> *"What should be included in 'capital'? In the national accounting systems presently in use, capital consists of produced durable inputs. However, from the viewpoint of the theory of production, it is evident that natural resource stocks and land should also be included in the list of durable inputs. In addition, stocks of inventories and goods in process should be included. However, the practical problem here is how to obtain data on stocks of resources and inventories when it is not available in our current accounting framework."*

In the applied productivity literature, the items included from the list are usually limited to equipment, structures, land and inventories. The reason why these types of capital are included while others are omitted is related to the difficulty of measuring these items *in a manner consistent with the production model inherent in the System of National Accounts*.

Measurement difficulties seem to be the root cause of these exclusions. In the case of financial assets, many relevant data are often available. Furthermore, management of financial assets is essential to a firm's existence. However, it is difficult to identify a systematic relationship between decisions about financial assets and production decisions. By excluding financial assets, productivity economists have effectively regarded portfolio management as an 'investor' issue. Miller and Modigliani (1966) discussed the conditions under which production decisions could be seen as separable from decisions affecting the firms' financial portfolio.

Intangible capital assets are excluded for slightly different reasons. While intangible capital may play a more direct role in production than financial assets, they are excluded because there is greater difficulty in measuring their services. Since these assets are intangible, we cannot rely on tying the quantity of services to the quantity of goods. Computer software can be used to illustrate the problem. It is not only difficult to identify the capital services—it is equally difficult to identify the capital good.

Why are equipment, structures, inventories and land included? Equipment and structures are capital goods which are reproducible (unlike land) and depreciable (they lose value as they age). We can readily determine the cost of producing each unit of these types of capital and we can identify 'real quantities' by a) counting them and b) observing how they deteriorate over time.

Land, like equipment and structures, is a fixed asset that can be readily measured. It differs in that it is generally assumed not to depreciate. If anything this makes it simpler to account for. In his *Principles*, Ricardo described the rental market for a fixed supply of land. While the total quantity of land may be fixed, land can be traded among sectors. Also, the characteristics of a plot of land from the standpoint of production can change, even if land itself is intrinsically the same. For example, development can occur nearby which may enhance the usefulness of the plot.

Inventories are goods and are therefore relatively easy to measure. However, the rationale for including inventories with capital is a bit less obvious to some observers since they are often not long-lived and do not resemble other assets in terms of durability. Goods held as inventories are often outputs (finished inventories) or inputs (purchased raw materials) of the firm. However, the same goods play a second role—that of capital—to the extent that firms deliberately maintain 'buffer stocks' of these goods to facilitate production. For example, raw materials are typically received in discrete batches, and significant amounts are stockpiled to protect against uncertainty over the timing of deliveries. Similarly, a firm stockpiles finished goods to ensure it can promptly fill new orders without excessive labour costs. In this sense, inventories play an important role in the production process and involve an opportunity cost that should be considered in the productivity measures.

4.3.2 Aggregation

4.3.2.1 Across Assets of Different Types

Once we have estimated capital stocks for various types of assets owned by an industry, we face the problem of aggregating these into a measure of total capital service input. We assume that capital services of each type of asset are proportional to its stock. Although the factors of proportionality are constant, the unit prices of capital are different for each type of stock.

We use these weights for aggregation rather than simply adding together the value of stocks (Appendix 4.B describes more formally the aggregation procedures used to arrive at the concept of capital services).

As indicated, capital theory comes into play on this issue. Property income R_{it} of industry i is the total rent received from the various assets a in each time period t

$$R_{it} = \sum_{a} c_{iat} K_{iat} \tag{5}$$

where K_{iat} is the capital stock of the ath asset and c_{iat} is its rental price defined in equation (4). We already have estimates of the stocks and, as mentioned earlier, of property income. The latter are assembled from data on return on capital by industry from the input-output tables. These procedures ensure sets of rental prices that precisely account for each industry's property income.

In implementing these methods, we solve equations (4) and (5) for the 'ex-post' actual rate of return r_{it}.

This system of equations is solved with the data on capital stocks K_{at} and estimates of property income R_{it}. We solve this system of equations separately for each of 122 industries (1980 SIC) spanning the Canadian business sector. We compute stocks and rental prices for 28 different types of assets.

4.3.2.2 Across Industries of the Business Sector

Once we have measures of the capital service of industries, they can be used to construct measures of capital input growth for more aggregate sectors. In aggregating capital across industries, the weights we use are the industry's shares in the aggregate sector's property income. Since property income is a part of each industry's value added, it is additive across industries. Therefore the industry shares within a sector add up to one.

The use of property income in aggregating industry capital is consistent with its use as capital's share in industry multifactor productivity measurement and with its use as the total rental cost for the various assets deployed by the industry. It is also consistent with Domar's (1961) notion of an aggregate production model that has been derived from outputs and inputs of the various industries within the business sector.

Use of property income to construct weights for aggregation has certain implications. Investors in all industries may face similar ex-ante interest rates and capital may be allocated to industries in the long run in such a way that the rental price of a particular type of asset is the same in all industries. However, from the ex-post perspective, some industries earn higher rates of return than others do. By giving more weight to the industries earning higher returns, we are effectively saying that their assets are generating more capital services.

4.4 From Theory to Practice: Some Measurement Issues

A number of issues face empirical researchers who try to measure the various components of the user cost formula defined in equation (4). These issues are related to the considerable time and effort required for the construction of the tax variables included in the user cost formula and by the difficulties in getting accurate estimates on the expected capital gains term, the rate of return and the depreciation rate.

4.4.1 The Rate of Return

The rate of return the investor uses to discount future rents while making investment decisions is sometimes called the *ex-ante* rate of return. The *ex-ante* rate of return is the 'hurdle' rate of return used by firms as an investment decision rule. However, the rate r_{it} which we use reflects the property income actually realized and is called an *ex-post* rate of return. In order to rationalize its use, we have to assume that there is no difference between *ex-ante* and *ex-post* rates of return. However, in reality, expectations often are not met and the result is a difference between these two rates of return.

Berndt and Fuss (1986) and Hulten (1986) have discussed how the 'shadow price' of capital, computed from data on property income, is consistent with an *ex-post* rate of return. Fluctuations in capacity utilization manifest themselves as fluctuations in the shadow price of capital and in the *ex-post* rate of return. They argue that the appropriate weight for capital in multifactor productivity measurement is based on property income.

The lack of consensus concerning measurement of the nominal discount rate r in Jorgenson's rental price formula is illustrated by Diewert (1980a, pp. 476-477) as follows:

> *"Which r should be used? If the firm is a net borrower, then r should be the marginal cost of borrowing an additional dollar for one period, while if the firm is a net lender, then r should be the one-period interest rate it receives on its last loan. In practice, r is taken to be either (a) an exogenous bond rate that may or may not apply to the firm under consideration, or (b) an internal rate of return. I tend to use the first alternative, while ... Jorgenson and his co-workers used the second. As usual, neither alternative appears to be correct from the theoretical a priori point of view; so again, reasonable analysts could differ on which r to use in order to construct a capital aggregate."*

4.4.1.1 The Internal Rate of Return

We begin with the internal nominal rate of return specification, developed in detail by Christensen and Jorgenson (1969), discussed in further detail by Fraumeni and Jorgenson (1980), and applied by the Bureau of Labor Statistics (BLS)(1983).

Combining equations (4) and (5), and assuming that the rate of return is the same for all assets but different across industries. The internal nominal rate of return r_t is

$$r_{it} = \frac{\left[R_{it} + \sum_{a=1}^{A} (-\delta_{ai} T_{it} q_{ait-1} K_{ait} + \Delta q_{ait} T_{it} K_{ait} + \phi_{it} \, q_{ait-1} K_{ait} \,) \right]}{\sum_{i=a}^{A} q_{ait-1} T_{it} K_{ait}}, \tag{6}$$

where

$$\Delta q_{ait} \equiv q^{*}_{ait} - q_{ait-1} \text{ and } T_{iat} = \frac{1-u_{it} z_{iat} - k_{iat}}{1-u_{iat}}.$$

When property income becomes negative, this method is not capable of generating reasonable capital rental prices. In particular, the implied shadow price of capital is, in such cases, negative, implying that the firm is not covering its unit variable costs. While such a situation may be possible in theory, one would not expect to observe this in practice over long periods of time, for firms have the option to shut down in the short run if the price does not cover unit variable costs.

One way of obtaining 'reasonable' rental price measures in such cases is to remove from the underlying calculations the elements causing the large fluctuations. In most cases, these elements are the capital gains term or the capital compensation. The standard practice in the applied economics profession includes employing a before-tax constant nominal rate of return (Coen 1975) or an estimate of the real rate of return (between 3 and 4 percent) that is equal to the industrial average (Fraumeni and Jorgenson 1980).[7] In our case, the problem of negative capital compensation experienced by some industries during recession periods is eliminated by calculating a four-year moving average.

4.4.1.2 The External Rate of Return

Many researchers have finessed the idea on the existence of a unique rate of return by assuming perfect arbitrage between financial and real capital and between real capital

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[7] A 3.5 percent constant real rate of return has been employed by the BLS (1983) in its multifactor productivity calculations for the agricultural sector, a sector in which capital compensation measures occasionally become negative.

of different types. In so doing, they are implicitly assuming that the real world is characterized by several closely related properties: a) that both the owners of real capital and business managers operate with perfect information; b) that physical capital is perfectly malleable and divisible; c) that incorrect capital formation decisions are easily reversible; d) that efficiently functioning used asset markets are readily available for all asset types; and e) that there is no divergence between the interests of corporate managers and the owners of corporate capital. If these conditions hold, then a unique (external or exogenous) rate of return can be used in the rental price calculation of all industries.

A number of studies of the user cost of capital have employed as a measure of the expected or *ex-ante* rate of return a bond yield taken from financial markets data. For U.S. studies, the most common are Moody rates for Aaa- or Baa-rated bonds, or long-term U.S. government bond yields (see Harper *et al.* 1989). In Canada, both the three-month Treasury Bill rate (McKenzie and Thompson 1997) and the long-term Canada bond rate (Harchaoui and Lasserre 1995) have been used. We refer to the specification of these rates of return as the external nominal rate of return model.

As an empirical alternative, therefore, we replace the nominal internal rate of return r_t in equation (4) with r_{ft}, the external nominal risk-free rate of return measured by market interest rates. Given the implied rental prices c_{ift} we recompute costs of capital for each asset as $c_{ift}K_{it}$, and then use $c_{Kt}K_t = \sum_{a=1}^{A} c_{ift}K_t$ to obtain new cost shares. Note that if this measure is used as an *ex-ante* measure of the cost of capital, unrealized expectations could result in a divergence between *ex-ante* and *ex-post* capital costs. As a measure of the implied 'surprise,' we take the ratio of actual capital compensation to the implied *ex-ante* capital compensation $\frac{R_t}{\sum_{i=1}^{N} c_{ift}K_t}$. This ratio can also be interpreted as the adjustment necessary to use the c_{ift} to apportion actual current capital compensation (see Harper *et al.* 1989).

However, many of the aforementioned conditions for the use of a single rate of return may not hold. For example, the perfect arbitrage argument probably breaks down because both the fixity and specificity of capital impede the capital stock adjustment process to changes in relative rates of return and limits the existence and the effectiveness of used asset markets as vehicles for correcting past capital-formation decisions. Further, the available evidence suggests that the interests of corporate management and stockholders are not always completely in accord (Myers and Majluf 1986). Whether or not deviations from these assumptions are serious is an empirical matter.

In the uncertain real world, different sources of financial capital have both different perceived risks and different costs. Debt is historically cheaper than equity and different industries incur different costs for externally raised capital. In fact, on this point, the available econometric evidence suggests that the use of industry-specific rates is an important key to obtaining well-behaved statements of production technology (Hazilla and Kopp 1984). Moreover, empirical studies suggest the existence and persistence of long run differences in rates of return at the firm level (Muller 1986) and industry level (Khemani and Shapiro 1990). As a result, it is our decision to use industry specific rates in our analysis.

It should be noted that alternate choices of the internal rate of return will affect the rates of growth of capital inputs only if they affect the relative weights that are applied to capital growth across industries. That is, it is not so much the mean level of the rate of return that matters as it is the relative values of the rate of return in calculating the weighted average of the rate of growth of capital over time. Using the internal rate of return provides a higher mean rate of return than does the long-term bond rate. But more importantly, it may give no greater weight in the index number formulae to different industries. To do so, it would have to be relatively higher in some industries than others.

4.4.2 Measuring the Capital Gain

The final refinement to the cost of capital estimation procedure involves the interpretation and measurement of the capital gain adjustment to the after-tax nominal cost of capital. Almost all formulations of industry rental prices found in the recent literature contain the expression—$r_{it} - \left(\frac{q^*_{iat} - q_{iat-1}}{q_{iat-1}}\right)$—defined to be the real after-tax opportunity cost of capital, where $\left(\frac{q^*_{iat} - q_{iat-1}}{q_{iat-1}}\right)$ is unambiguously defined as the ‘inflation rate’. There are two questions that need to be resolved. First, what is the underlying assumption about expectations? Second, how do we measure capital gains?

In Jorgenson (1963, 1965) and in Hall and Jorgenson (1967), the expected capital gains term is set equal to zero since “*….we assume all capital gains are regarded as ‘transitory’*” (Jorgenson 1963, page 249). In this case, the nominal and real rates of return are the same. Some argue that there is a defensible basis for making this assumption: Capital gains are not realized until an asset is sold. Thus, if most capital goods are held either a) to the end of their useful service lives or b) until obsolescence has effectively neutralized the potential gains, the term $\left(q^*_{iat} - q_{iat-1}\right)$ has no practical significance in the capital investment decision.

In Jorgenson and Siebert (1968a, b), two models are compared to the first assumption of ‘transitory capital gains’: One with perfectly anticipated capital gains where $q^*_{iat} = q_{iat}$ and the other where expectations are myopic and expected capital gains are zero, i.e., $q^*_{it} = q_{it-1}$. Empirical results reported by Jorgenson and Siebert indicate a modest preference for the former over the latter in explaining the investment behaviour of individual firms. It is perhaps in part for this reason that since the late 1960s, Jorgenson and his associates have only used the perfectly anticipated capital gains assumption in their empirical work on investment and productivity (see Jorgenson and Griliches 1967; Fraumeni and Jorgenson 1980; Jorgenson and Sullivan 1981 and Jorgenson and Fraumeni 1981).

As for the measurement of capital gains, Jorgenson and Siebert suggested three possibilities: a) the use of the consumer price index—the conventionally understood definition; b) the output price index of the industry; and c) the use of the price index for fixed assets used by the industry.

While appropriate for certain types of theoretical expositions, options a) and b) are of questionable value for industry-specific empirical studies on capital formation. In developing the arguments needed to implement the investment decision model, it is more reasonable to assume that entrepreneurs formulate measures of the asset price inflation that they expect over the life of a contemplated investment. This is exactly what option c) suggests. A variant of option c) is to employ as an estimate of q_{it}^* a moving average of previous asset prices (Gillingham 1980). Both option c) and its variant will be investigated.

4.5. Analysis of the Results

This section discusses several alternate estimates of the user cost of capital c_{iat} and capital stock K_{iat} along with those of their different components.

4.5.1 The User Cost of Capital and Its Components

Economists have studied the cost of capital for the past four decades, but especially in recent years as a result of changes introduced in the Tax Act of 1981 and 1987 (Boadway and Kitchen 1999). Holding constant macroeconomic factors such as interest rates and expected inflation, the 1981 Tax Act lowered the cost of capital by introducing more accelerated depreciation. In a reversal of this policy, the 1986 Act lengthened tax lives and mandated straight-line recovery for structures. It also eliminated the investment tax credit, which had been available for all equipment and limited categories of structures.

Despite the interest of analysts on the effect of tax policy on capital costs, tax policy is not necessarily the only factor influencing expected capital costs. In a much-cited article in the United States, Bosworth (1985) noted that investment following the 1981-1982 recession was strongest in computers and automobiles, two categories not particularly advantaged by the 1981 tax reform. Bosworth concluded that prices of capital goods and movements in the cost of funds played a greater role in determining the cost of capital. More recently, Auerbach and Hassett (1991) found that investment in equipment was somewhat influenced by the Tax Reform Act of 1986, but that investment in structures did not appear to be affected by the revised tax provisions.

4.5.1.1 Tax Rates

Corporate income tax rates are captured through the component u_{it} of the user cost of capital. Until the substantial reduction under the 1986 Tax Reform Act, movements in the statutory corporate income tax rate were minor, thus having little influence on the cost of capital. The average corporate income tax rate for the business sector, shown in Figure 4.1, decreased from 49 percent during the 1961-1987 period to 44 percent during the 1987-2000 period. The average corporate income tax rate for the manufacturing sector followed a more pronounced downward trend between these two periods.

Figure 4.1 Average Corporate Income Tax Rate

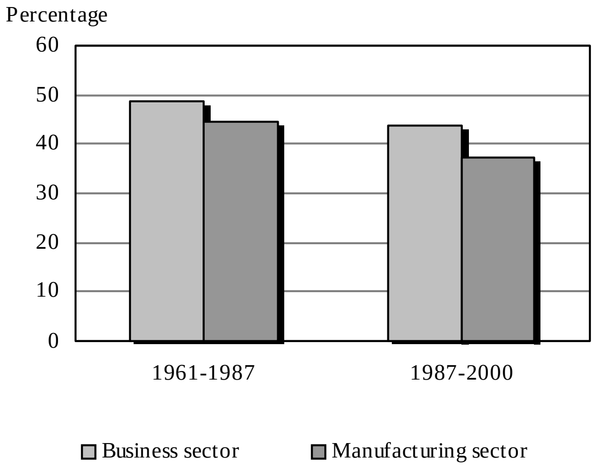
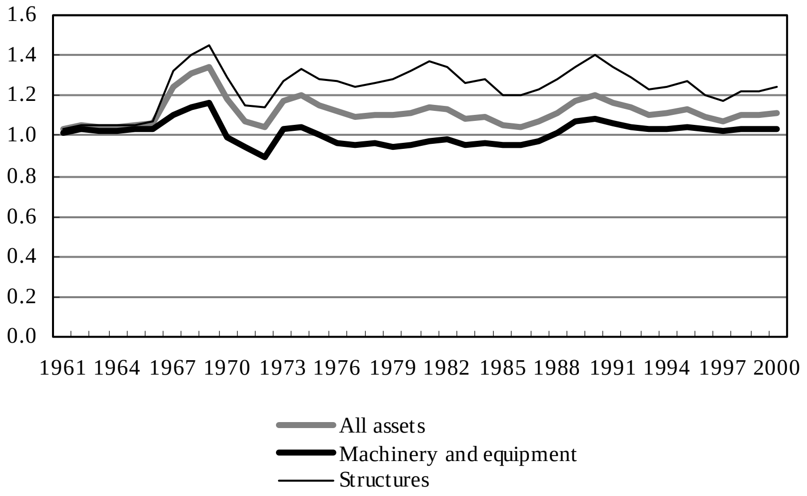


Figure 4.2 Tax Price, Manufacturing Sector



4.5.1.2 Tax Price

The variable $\left(\frac{1-u_{it}z_{iat}-k_{iat}}{1-u_{it}}\right)$, which represents the tax price of the asset, allows for the variation of income tax allowances according to different industries, asset types, and variations in allowances over time. Changes in corporate profit taxes over time are also allowed for. The tax price can be decomposed into two major components: First, the taxation of returns $\left(\frac{1}{1-u_{it}}\right)$; this component indicates that, as a result of the income tax rate u_{it}, to earn one dollar net of tax, capital must earn $\left(\frac{1}{1-u_{it}}\right)$ gross of tax. Second, the term $(1-u_{it}z_{iat}-k_{iat})$ indicates the effective reduction of the purchase price resulting from investment incentives. Some assets are eligible for an investment tax credit at rate k_{iat}. The variable z_{iat} represents the present discounted value of depreciation allowances per dollar of purchase price. These allowances are deductible from taxable income, thus saving the firm $u_{it}z_{iat}$ in tax obligations.

Corporate taxes aside, the provisions increase the after-tax returns on investment and lower the rental price of capital. A downward trend of the tax price can therefore be interpreted as a fiscal policy that promotes investment as it reduces the cost of capital, and vice versa for an upward trend.

Since tax price differs more across assets than industries, Figure 4.2 illustrates the effect of incentives on structures, machinery and equipment and all assets for the manufacturing sector. It is clear from Figure 4.2 that since the late 1980s, the tax price experienced a steady decline, albeit not in the same order of magnitude as the one that occurred in the early 1970s. The downward trend is steeper for structures in comparison to machinery and equipment.

Table 4.1 Components of the User Cost of Capital: Oil and Gas Industries

Year	Rental Price c_{iat}	Rate of Return $T_{it}r_{it}q_{iat-1}$	Depreciation $T_{it}\delta_{ia}q_{iat-1}$	Capital Gains $T_{it}\Delta q_{iat-1}$	Indirect Taxes $\phi_{iat}\ q_{iat-1}$
1961	0.03042	0.01925	0.01292	0.00195	0.00020
1962	0.02392	0.01616	0.01329	0.00589	0.00037
1963	0.02948	0.02076	0.01366	0.00535	0.00042
1964	0.03800	0.03614	0.01411	0.01262	0.00038
1965	0.04706	0.04007	0.01514	0.00855	0.00041
1966	0.02894	0.02421	0.01601	0.01174	0.00046
1967	0.05849	0.04094	0.02081	0.00394	0.00068
1968	0.03782	0.03411	0.02246	0.01964	0.00089
1969	0.04543	0.03586	0.02479	0.01639	0.00117
1970	0.04080	0.03394	0.02521	0.01971	0.00136
1971	0.06672	0.05984	0.02413	0.01847	0.00121
1972	0.07921	0.07930	0.02523	0.02672	0.00140
1973	0.06510	0.10201	0.02966	0.06834	0.00177
1974	0.08153	0.12083	0.03772	0.07961	0.00259
1975	0.11557	0.11912	0.04112	0.04846	0.00378
1976	0.13237	0.13078	0.04388	0.04716	0.00487
1977	0.14144	0.14705	0.04606	0.05566	0.00400
1978	0.16628	0.16851	0.05165	0.05934	0.00546
1979	0.12040	0.14231	0.05767	0.08359	0.00402
1980	0.13705	0.15625	0.06631	0.09054	0.00503
1981	0.11457	0.12915	0.07722	0.09873	0.00693
1982	0.08216	0.01645	0.08228	0.02720	0.01063
1983	0.13223	0.08270	0.07834	0.04128	0.01246
1984	0.15990	0.11310	0.08331	0.04488	0.00837
1985	0.19304	0.09050	0.08517	-0.01042	0.00696
1986	0.18190	0.13533	0.08425	0.04278	0.00510
1987	0.33303	0.25864	0.09069	0.02649	0.01019
1988	0.30727	0.24200	0.09455	0.03399	0.00471
1989	0.15830	0.08714	0.10101	0.03472	0.00487
1990	0.10229	0.08376	0.10455	0.09117	0.00514
1991	0.23613	0.16002	0.10639	0.03574	0.00546
1992	0.25215	0.17752	0.10474	0.03364	0.00352
1993	0.18845	0.13178	0.10264	0.05161	0.00564
1994	0.29913	0.18995	0.10876	0.00554	0.00595
1995	0.25627	0.12181	0.11298	-0.01585	0.00564
1996	0.21069	0.09980	0.10398	-0.00063	0.00628
1997	0.27132	0.16628	0.10035	0.00107	0.00576
1998	0.25024	0.13904	0.10577	-0.00021	0.00521
1999	0.28131	0.17073	0.10572	0.00000	0.00486
2000	0.29477	0.18213	0.10809	0.00000	0.00455
Mean	**0.14478**	**0.10763**	**0.06357**	**0.03064**	**0.00422**
Standard Deviation	**0.09353**	**0.06307**	**0.03660**	**0.03007**	**0.00302**

Note: Asset: Oil facility construction; c = rental price of capital; r = internal rate of return; q = price of the asset; T = tax price; δ = depreciation rate; ϕ = property tax rate.

4.5.1.3 Cost of Funds

The other term in the user cost of capital formula is the annual economic cost of using the asset. It consists of a real cost of funds $r_{it} - \frac{(q^{*}_{iat} - q_{iat-1})}{q_{iat-1}}$ plus the rate of economic depreciation for the asset δ. The cost of funds depends both on the risk premium required by financial markets and on how businesses finance their capital expenditures. Studies of the cost of capital have used different methodologies to measure this term, and no consensus has emerged on which method is most appropriate (Bosworth 1985).

This study applies the 3-5 year Canada bond rate and the internal rate of return from the Input-Output Tables to all assets and industries. The nominal internal rate of return is usually higher than the 3-5 year Canada bond rate as the former is a risk-adjusted rate of return. The higher volatility shown by the internal rate of return is indicative of the risk factor.

Movement in the rate of return tended to make investment less costly in the second half of the late 1960s and more costly in the 1980s. As indicated in Figure 4.3, the real rate of return $r_{it} - \frac{(q^{*}_{iat} - q_{iat-1})}{q_{iat-1}}$ was fairly level from the mid-1960s through the mid-1970s, and then rose sharply during the 1980s and the early 1990s. It remained high in the latter half of the early 1990s.

These changes tended to influence overall levels of investment: increases in the real rate of return blunted some of the stimulus to investment associated with the 1981 Tax Reform Act and reinforced the increased tax costs from the 1987 Act. They also may explain some of the shift away from structures observed during the late 1980s, since capital costs for long-lived assets are particularly sensitive to the cost of funds.

4.5.1.4 Estimates of the User Cost of Capital

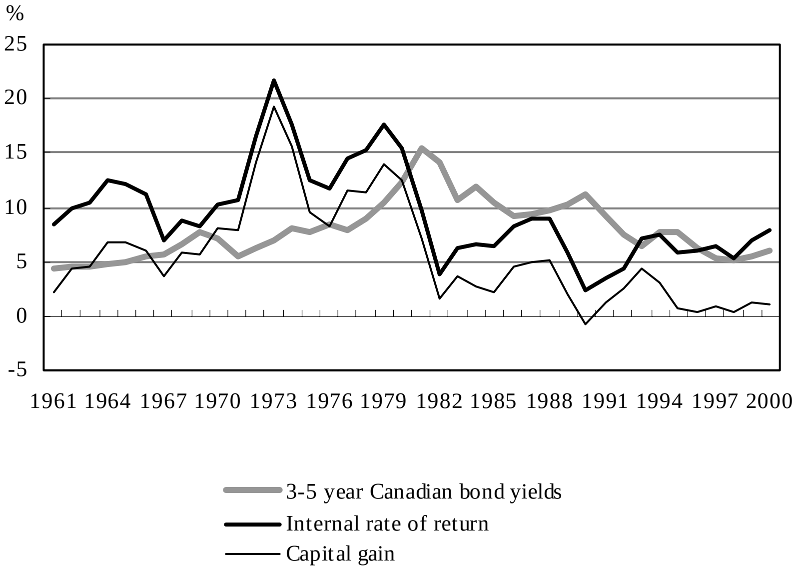
We now examine the estimates of the rental price of capital c_{iat} defined in equation (4) and its components conveniently divided into four components:

a) the rate of return $T_{iat} r_{it} q_{iat-1}$;
b) depreciation $T_{iat} \delta_{ia} q_{iat-1}$;
c) capital gains $T_{iat} \Delta q_{iat-1}$;
d) indirect taxes $\phi_{iat}\, q_{iat-1}$.

We illustrate the pattern of each of these components in Table 4.1 with oil facility construction used by oil and gas industries over the 1961-2000 period.

Substantial fluctuations occurred in the estimates of user cost, with large drops experienced in 1982 and during the 1989-1990 period. The fluctuations around trend experienced by the user cost of capital are largely attributable to the rate of return and, to a lesser extent, capital gains. The sharp drop in the rental price during these years is due to a substantial decline in the rate of return, largely reflecting the impact of the last two recessions on oil and gas industries.

Figure 4.3 Nominal Cost of Funds and Capital Gains



4.5.2 The Capital Stock Components: Produced Assets and Land

Recall that capital compensation as defined in equation (5) has two components: the rental price (or user cost) and the volume of the asset. The previous section described the trend in the user cost of capital and its major components. In the following section, we provide an overview of the methodology used to construct estimates of the volume of capital assets and an analysis of the results. The analysis is primarily focused on the components of produced capital stock estimates (i.e., the series, the initial capital stock and depreciation estimates) and land estimates, both of which represent the bulk of capital input estimates.

4.5.2.1 Produced Assets

Measurement of capital stock estimates in equation (2) are constructed by the use of a form of the perpetual inventory method. To construct a capital stock series, the analyst usually starts at some initial period zero with a measure of the initial capital stock K_o, and then calculates successive values of K_t by substituting the depreciation rate and the elements of an investment series into equation (2).

By successive backward substitution for K_{t-1} in equation (2), we can relate K_t directly to the initial capital stock value, K_o. K_t becomes a weighted sum of all past levels of investment and the depreciated value of the initial real capital stock

$$K_t = \sum_{j=0}^{t-1} (1-\delta)^j I_{t-i} + (1-\delta)^t K_0 . \qquad (7)$$

Measurement problems in the capital stock series may arise from any of the three components of equation (7): the I_t series, δ, or K_o.

Table 4.2 Business Sector's Estimates of the Initial Capital Stock for Machinery-Equipment and Structures

	β_o	β_K	γ	$\hat{K}_o \equiv \frac{\hat{\gamma}}{\beta_K}$	R^2	Durbin-Watson
Machinery and Equipment	0.771	0.41	12.9	27.2	0.89	2.15
	(1.152)	(2.749)	(3.397)			
Structures	0.157	0.68	55.7	81.5	0.77	2.05
	(0.774)	(1.924)	(2.214)			

t-statistics in parentheses.

4.5.2.1.1 Initial Capital Stock

Various methods have been used to estimate the initial capital stock K_o, but virtually all researchers acknowledge that the starting values are subject to errors. As a result, where at all possible, they have chosen starting dates for the capital stock calculation 10, 20 or more years before the beginning of the estimation period—relying on the implication of equation (7) that the impact of K_o on subsequent values of the capital stock decays exponentially. In this section, we propose an alternative approach to the construction of the initial capital stock.

Consider the following production function under constant returns to scale

$$\ell nQ_t = \beta_o + \beta_K K_t + (1-\beta_K)\ell nL_t + \varepsilon_t \tag{8}$$

where Q_t, K_t and L_t are real output, capital stock and the number of hours worked, respectively. Output and labour are both expressed in log form; β_o and β_K are the unknown parameters and ε_t is an independently distributed random error. Substitute the alternative definition of capital stock $K_t = \tilde{I}_t + (1-\delta)^t K_0$, where $\tilde{I}_t \equiv \sum_{j=0}^{t-1}(1-\delta)^j I_{t-i}$ is the weighted sum of past investments, in equation (8), we get

$$\ell n\left(\frac{Q_t}{L_t}\right) = \beta_o + \beta_K\left(\tilde{I}_t - \ell nL_t\right) + \gamma D_t + \varepsilon_t \tag{9}$$

where $\gamma \equiv \beta_K K_o$ is a constant like any other parameter in equation (9) and $D_t \equiv (1-\beta)^t$.

The estimation of equation (9) gives the parameter estimates $\widehat{\beta}_K, \hat{\gamma}$ and, therefore, $\hat{K}_o \equiv \frac{\hat{\gamma}}{\beta_K}$. Using the generalized least square method, the model (9) was separately estimated for machinery and equipment and structures as these two capital asset types have a different impact on the business sector's labour productivity level in equation (9). The results shown in Table 4.2 indicate the parameters β_K and γ are both positive and significant at 5% level of significance. The model shows no evidence of spurious

Table 4.3 Contribution of Business Sector Industries to the Growth of Information Technology Real Investment (Percentage)

	1981-2000	1981-1988	1988-2000
Agriculture	0.4509	0.0225	0.7031
Fishing and Trapping	0.0092	0.0031	0.0150
Logging and Forestry	0.0385	0.0601	0.0295
Mining	0.1771	0.1562	0.2093
Crude Petroleum and Natural Gas	0.2325	0.1683	0.2715
Quarry and Sand Pit	0.0207	0.0224	0.0202
Services Incidental to Mineral Extraction	0.1242	0.1055	0.1439
Food	1.0151	0.7245	1.1357
Beverage	0.2928	0.2202	0.3219
Tobacco Products	0.1294	0.0507	0.1730
Rubber Products	0.2080	0.2566	0.1840
Plastic products	0.2817	0.3543	0.2299
Leather and Allied Products	0.0251	0.0366	0.0150
Primary Textile	0.0585	0.0956	0.0370
Textile Products	0.0300	0.0560	0.0110
Clothing	0.1934	0.1749	0.2210
Wood	0.2979	0.2687	0.3098
Furniture and Fixture	0.1210	0.0922	0.1304
Paper and Allied Products	0.7127	0.7829	0.7246
Printing, Publishing and Allied	0.9452	0.4226	1.2155
Primary Metal	0.9990	1.5687	0.7972
Fabricated Metal Products	0.4534	0.7070	0.2818
Machinery (Except Electrical Machinery)	0.5470	0.4389	0.5641
Aircraft and Aircraft Parts Industry	0.1558	0.1984	0.1210
Transportation Equipment	1.1444	1.7276	0.7195
Electrical Products	0.7428	0.9302	0.6083
Communication and Electronic Equipment	0.9927	1.2863	0.7686
Office, Store and Business Machines	0.4360	0.6481	0.3185
Non-metallic Mineral Products	0.1614	0.2589	0.1454
Refined Petroleum and Coal Products	0.3511	0.4019	0.3129
Chemical and Chemical Products	0.9916	0.8772	1.0832
Pharmaceutical and Medicine	0.1468	0.1497	0.1517
Other Manufacturing	0.5542	0.5553	0.5160
Construction	1.4228	1.7266	1.3120
Transportation	2.6414	1.9618	2.8221
Pipeline Transport	0.3343	0.1201	0.4530
Storage and Warehousing	0.1023	0.0604	0.1164
Communication	14.2605	10.2797	17.7388
Other utility	6.0068	8.1463	4.5614
Wholesale Trade	5.4526	3.2239	6.6863
Retail Trade	6.4985	4.1563	7.8001
Finance and Real Estate	22.5765	21.3661	22.6004
Insurance	1.6581	2.5720	1.0207
Business Services	10.9975	9.3444	11.9040
Educational Service	0.1659	0.2637	0.1108
Health and Social Service	0.6868	0.8744	0.5974
Accommodation and Food Services	1.8002	3.4771	0.8834
Amusement and Recreational Services	1.1296	1.5759	0.8646
Personal and Household Services	0.1860	0.3413	0.1115
Other Services	11.0400	16.6880	7.9278
Total	**100.0000**	**100.0000**	**100.0000**

correlation as indicated by a reasonably high level of the R^2 (a maximum of 0.87) and the estimates of the initial capital stock, evaluated at 81.5 and 27.2 billion of 1961 dollars, are statistically significant. These estimates were then allocated by industry and asset categories according to the 1961 investment series.

4.5.2.1.2 Investment

The composition of business investment in Canada changed dramatically during the last two decades. Workplaces were transformed as a result of investments in information technology equipment, such as computers, software and communications equipment (see Chapter 1). Businesses built new office towers and shopping malls, but few industrial facilities. These changes are reflected in the contribution of information technology, other machinery and equipment and structures to the change in aggregate investment during the last two decades as well as in the contribution of each industry to the growth of aggregate investment.

As shown by Figure 4.4, the contribution of information technology equipment to the increase in real investment has risen significantly. This category accounted for 28 percent of the growth of total real business investment during the 1981-1988 period. During the 1988-2000 period, its contribution increased sharply, contributing 34 percent of real total business investment growth. A similar increase was experienced by the contribution of structures to real business sector investment between these two periods, while the contribution of other machinery and equipment declined sharply.

Figure 4.4. Average Contribution of Asset Classes to Business Sector Investment Growth

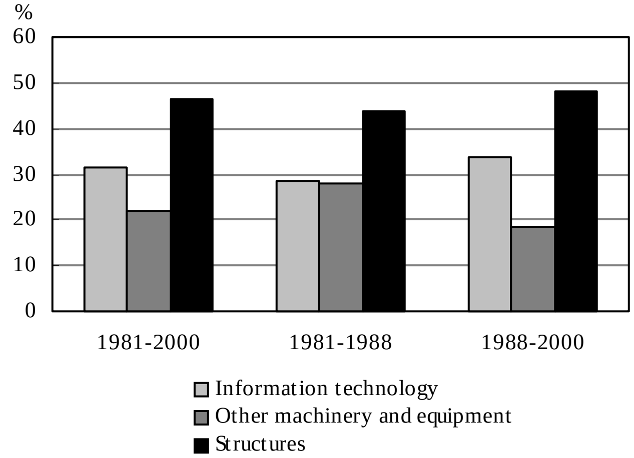


Table 4.3 shows the contribution of different industries to business sector real investment in information technology between 1981 and 2000. Three industries alone—communication, finance and real estate and business services—have contributed about 41 percent of the growth in information technology real investment during the 1980s. This contribution jumped to 52 percent in the 1990s, primarily as a result of the shift in the contribution of communication industries. Amongst the other major industries that saw their contribution increase during these two periods are wholesale (from 3.2 percent to 6.7 percent) and retail trade industries (from 4.2 percent to 7.8 percent), while the contribution of finance, insurance and real estate and business service industries increased only moderately.

4.5.2.1.3 Depreciation

In the perpetual inventory method, the pattern of depreciation for a given asset is determined by its 'depreciation profile.' The depreciation profile for a given type of asset describes the pattern of how, in the absence of inflation, the price of an asset of that type declines as it ages. The methodology used by the productivity program for estimating

Figure 4.5 Distribution of Inventories by Major Sectors (Current Prices)

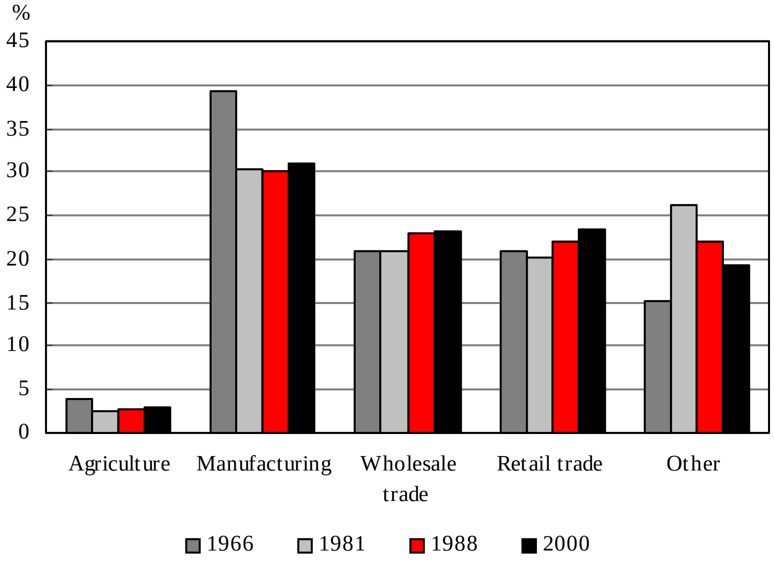


Figure 4.6 Inventories in Constant Prices

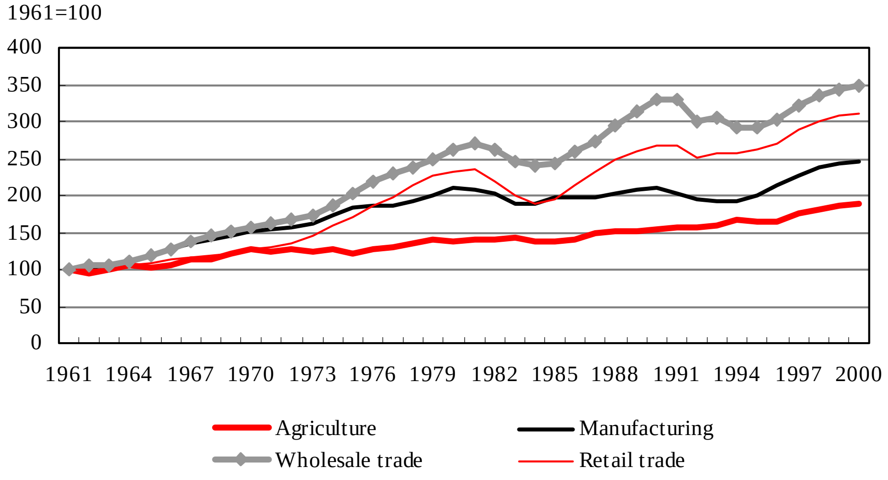
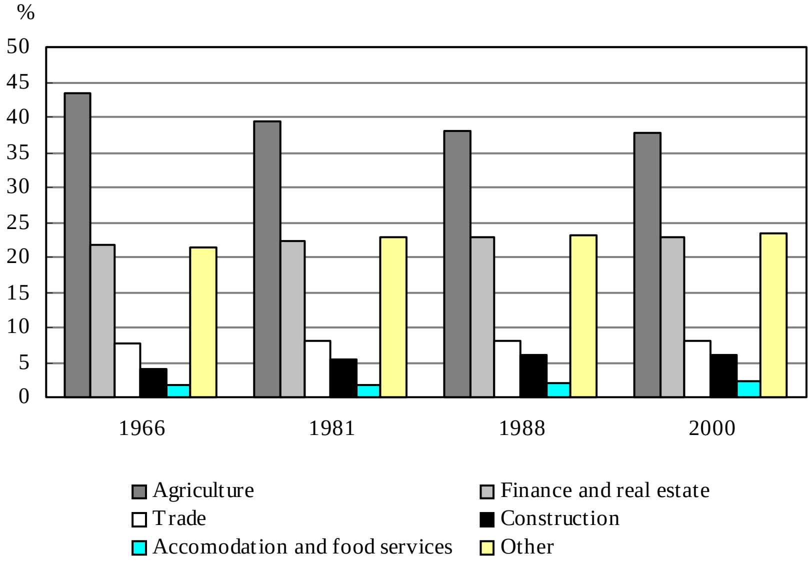


Figure 4.7 Distribution of Land by Major Sectors



depreciation is based on a maximum likelihood survival model that produces econometric estimation of depreciation rates (see Chapter 2).

The profile for 28 types of assets used by different industries is estimated using a rich dataset of used asset prices that includes information on retirement. The results suggest that, in general, depreciation profiles are consistent with the geometric pattern of price declines. Consequently, in the estimates used to construct capital stock estimates, the depreciation profiles for most assets were assumed to be strictly geometric.

The geometric depreciation rates used by Statistics Canada's productivity program to derive the estimates of net stocks and depreciation for 19 non-residential assets are shown in Table 4.4. As one may expect, the depreciation rates are particularly high for computers (51 percent) and communication equipment (20 percent); they are low for buildings (7 percent). Other structure-type assets, such as road, highway and airport runway construction, electric power, dams and irrigation construction, and gas and oil facility construction, display depreciation rates of 10, 6 and 8 percent, respectively).

In the case of roads, highways, dams and irrigation, their high depreciation rates partly reflect the impact of the difficult Canadian winter climate. As for gas and oil facility construction assets, the high depreciation rate reflects to a large extent the irreversibility effect[8]. In mining industries, investment expenditures are sunk costs because they are often firm or even plant specific. An oil and gas facility cannot be used in the copper, asbestos or in any other mineral industry, as the technology is specific to the type of mineral extracted. Because the resale value of the asset is small even though it has been in use for a short period of time, these sorts of assets experience fast depreciation rates on used asset markets.

4.5.2.1.4 Inventories

A treatment of inventories that is suitable for productivity measurement can be found in Diewert and Smith (1994). We follow their treatment of inventories in our multifactor productivity estimates. Since there is no investment tax credit, discounted value of depreciation allowances, or economic depreciation, the user cost formula (4) simplifies to

$$c_{iat} = q_{iat-1}\left(\frac{\left[r_t - \dfrac{\left(q_{iat}^{*} - q_{iat-1}\right)}{q_{iat-1}}\right]}{1-u_{it}}\right)$$

Figure 4.5 shows that in 2000, more than three-quarters of inventories are distributed between manufacturing and trade industries, down from 81 percent in 1966. Over the 1966-2000 period, manufacturing experienced a decline in its share of inventories to the benefit of trade industries who posted the highest average annual growth rate (Figure 4.6).

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[8] Irreversibility is nowhere as obvious as in the mining sector where the equipment is bulky and even ore specific. In a recent paper, Harchaoui and Lasserre (2001) formulated and tested a model of investment under irreversibility using an option pricing framework. The evidence suggested that, for a sample of Canadian mines during the 1960-1980 period, the hypothesis of irreversibility cannot be rejected at a high level of significance. For a general discussion on the importance of irreversibility, see Dixit and Pindyck (1994).

Table 4.4 Geometric Depreciation Rates by Asset for Non-residential Capital Stock

Assets	Median Depreciation Rate
Office Furniture, Furnishing	0.33
Computers and Office Equipments	0.51
Household and Services Machinery and Equipment	0.14
Electrical Industrial Machinery and Equipment	0.19
Non-electrical Industrial Machinery and Equipment	0.22
Industrial Containers	0.05
Conveyors and Industrial Trucks	0.18
Automobiles and Buses	0.20
Trucks (excluding industrial trucks) and Trailers	0.20
Locomotives, Ships and Boats and Major Replacement Parts	0.12
Aircraft, Aircraft Engines and Other Major Replacement Parts	0.06
Communication Equipments	0.20
Other Equipments	0.20
Non-residential Building Construction	0.07
Road, Highway and Airport Runway Construction	0.10
Gas and Oil Facility Construction	0.08
Electric Power, Dams and Irrigation Construction	0.06
Railway and Telecommunications Construction	0.10
Other Engineering Construction	0.08
Total Non-residential Capital Stock	**0.14**

4.5.2.2 Land

Like subsoil and timber assets in the case of mineral industries, land is a key input in the agriculture sector which accounts for about 38 percent of land use by the business sector in Canada in 2000, down from 43 percent in 1966 (Figure 4.7). However, a number of unique attributes set land apart from other resources. First, land is generally not a depletable asset; therefore it does not depreciate over time. Second, location is key in determining the use of land. Third, the total stock of land is, for all intents and purposes, fixed. Since in many productivity studies, land is held fixed, it is often neglected as an input into production. However, even though the quantity of land is fixed, its quality-adjusted measure is not and so neglecting land can have an effect on aggregate input growth.

The approach used in the construction of the stock of land is strictly analogous to the approach taken for data on capital or labour input. Land services represent the quantity of land input, just as capital services represent the quantity of capital input. Measures of land services are derived by representing the stock of land at each point of time as a weighted sum of various categories of the stock of land (by province). Rental rates for land services provide the basis for property compensation, just as wage rates provide the basis for labour compensation. Data on rent is available in a readily accessible form only for the portion of agricultural land engaged in an active rental market. However, rental value of other agricultural land types can be imputed on the basis of the estimates of land by type of tenure and property compensation for the rented land.

The construction of a revised index of real land input has to divide the value of land services between price and quantity with price corresponding to the rental rate and quantity as the amount of land services utilized. This division is precisely analogous to the separation of the value of labour services between a wage rate and the quantity of labour services.

Agriculture data provide information on the volume of land and rental prices classified according to various characteristics such as the province, farm size and types of farms. The quality-adjusted stock of agricultural land was estimated using the assumption that the bulk of the heterogeneity in the quality of land can be captured through the provincial dimension. Other dimensions such as the type of farms may also introduce additional heterogeneity but were ignored at this point for the sake of simplicity.

Data on total area of farms were collected by province for the 1961 to1996 period using the Census of Agriculture. The concept of total area of farms encompasses all categories of land that enter into the activities of farms. This includes improved land (such as land under crop, pasture, summer fallow and other improved land) and unimproved land (woodland and other unimproved land).

The value of rent, available only for land that is leased or rented, covers roughly 30 percent of the total area of farms in Canada. Rent includes cash rent gross of taxes and share rent. For property such as land with an active rental market the separation may be carried out by means of market data on rental rates and corresponding data on the tenure of land. This method may be extended from rental property to property utilized by its owners if rental market values reflect the implicit rentals paid by owners for the use of their property. An imputation of this type is employed in the Canadian System of National Accounts in the measurement of services of owner-occupied housing. A precisely analogous imputation occurs in measuring labour services of the self-employed. The assumption that within the same province the competitive process ensures that the rental price of an acre of land is identical for leased or owned land was used to estimate the value of rent for the whole area of farms in Canada.

The following steps outline the procedure used to arrive at the Fisher Ideal Index of the quality adjusted stock of agricultural land:

1) $L_{i,j,t}$ is the total area of farms by tenure type $i = o, r$ (owned vs. rented) and by province j in year t;

2) $R_{r,j,t}$ is the total value of rent, which includes the rent paid in cash (cash rent) and on a share crop basis (share rent) for land and buildings rented from the government or private sector, including other farmers. The cash rent includes the taxes paid on property rented from others;

3) The rental price of one acre of rented land is:

$$c_{r,j,t} = \frac{R_{r,j,t}}{L_{r,j,t}}$$

and is assumed to be identical to the rental price of owned rent:

$$c_{r,j,t} \equiv c_{j,t}$$

4) The quality adjusted index of agricultural land $\tilde{L}_{t,t-1}$ between two adjacent periods is a Fisher (F) chained index defined as a weighted average of the index of the provincial area of farms between t and $t-1$, that is

$$\tilde{L}^{F}_{t/t-1} = \left(\tilde{L}^{L}_{t/t-1} \times \tilde{L}^{P}_{t/t-1}\right)^{\frac{1}{2}}$$

where

$$\tilde{L}^{L}_{t/t-1} = \sum_{j=1}^{10}\left(\frac{L_{j,t}}{L_{j,t-1}}\right)\left(\frac{c_{j,t-1}\cdot L_{j,t-1}}{\sum_{j=1}^{I} c_{j,t-1}\cdot L_{j,t-1}}\right) \text{ and}$$

$$\tilde{L}^{P}_{t/t-1} = \sum_{j=1}^{12}\left(\frac{L_{j,t}}{L_{j,t-1}}\right)\left(\frac{c_{j,t}\cdot L_{j,t-1}}{\sum_{j=1}^{12} c_{j,t}\cdot L_{i,t-1}}\right).$$

The construction of non-agricultural land in constant and current prices over the 1961-1997 period required various steps. We begin with the business sector's estimates for area of land available on a quenquennial basis from Statistics Canada's environmental accounts. Estimates of non-agricultural land were then derived as the difference between the area of business sector land and that used up by the agriculture sector. These estimates are then broken down by industry using the information on property taxes available from the Input-Output Tables to obtain the area of land by industry. Estimates of land in current prices are derived as follows: First, book value industry estimates of non-agricultural land were derived from corporate balance sheets produced by the Industrial Organization and Finance Division of Statistics Canada. These estimates were then turned into current price estimates using the ratio of current value to book value of non-agricultural land, respectively available from the National Balance Sheet Accounts and corporate balance sheet accounts.

Once a stock is estimated for land, a user cost equation similar to equation (4) is estimated for each asset in each ownership sector. Since there is no investment tax credit, discounted value of depreciation allowances, or economic depreciation, the user cost equation simplifies to:

$$c_{iat} = q_{iat-1}\left(\frac{\left[r_t - \frac{(q^{*}_{iat} - q_{iat-1})}{q_{iat-1}}\right]}{1-u_{it}} + \phi_{it}\right)$$

4.5.3 Measurement of the Effect of Changing Capital Composition under Alternate Estimates of the User Cost of Capital

4.5.3.1 On Capital Composition Effect

The growth of capital input under assumptions of heterogeneity is derived from an index that weights the growth in capital for different assets and industries by the rental price of capital, or more appropriately, by the share of that asset/industry class in the total capital cost. As such, this index can differ from an index that is just derived from the unweighted growth in the value of all assets. It will be higher than the latter to the extent that growth is coming mainly in those asset classes that have a relatively high rental cost of capital—either those in risky, higher return industries, or in assets with high rates of depreciation, i.e., computers. The difference between the growth of capital stock that weights different assets by relative unit capital costs and the growth in capital that is derived by assuming all assets provide the same capital services per dollar of assets measures the effect of the changing composition of capital—sometime referred to as the effect of changes in quality of capital.

We compare and evaluate the composition effect under five alternate capital rental price formulae discussed in Section 4.4. Once estimates of rental prices c_{iat} and capital stocks K_{iat} at the asset level are separately measured, they are used to construct series on capital services $\tilde{K}_{it}$ using a chain Fisher index for the industry i, the asset a and two adjacent periods t and $t-1$ (see Appendix 4.B for details):

$$\tilde{K}^{F}_{i,t/t-1} = \left(\tilde{K}^{L}_{i,t/t-1} \times \tilde{K}^{P}_{i,t/t-1}\right)^{\frac{1}{2}}, \tag{10}$$

where $\tilde{K}^{L}_{i,t/t-1}$ and $\tilde{K}^{P}_{i,t/t-1}$, the Laspeyres and Paasche indices of capital services respectively, are defined as follows:

$$\tilde{K}^{L}_{i,t/t-1} = \frac{\sum_{a=1}^{A}\left(\frac{K_{iat}}{K_{iat-1}}\right)c_{iat-1}K_{iat-1}}{\sum_{a=1}^{A}c_{iat-1}K_{iat-1}} \quad \text{and} \quad \tilde{K}^{P}_{i,t/t-1} = \frac{\sum_{a=1}^{A}\left(\frac{K_{iat}}{K_{iat-1}}\right)c_{iat}K_{iat-1}}{\sum_{a=1}^{A}c_{iat}K_{iat-1}}. \tag{11}$$

Equations (10) and (11), which demonstrate the important role of the rental price of capital in capital services aggregation estimates, have the following heuristic interpretation: the change in aggregate capital service flow is a weighted sum of the change in the a asset-specific capital stock, where the weights are defined in terms of the rental cost of capital.

This aggregation of capital services weights each type of capital by its relative rental cost share, and should be distinguished from the direct summation of capital stock defined as

$$K_{it} = \sum_{a=1}^{A} \bar{K}_{iat} \cdot \qquad (12)$$

The capital composition effect defined as $\frac{\tilde{K}_{it}}{\bar{K}_{it}}$ (see equations (10) and (12) above) captures the extent to which capital mix shifted toward shorter-lived equipment and away from structures and land.

The composition of capital changed over the years as investment in shorter-lived equipment contributed to the growth of aggregate investment than longer-lived structures (see Table 4.3). Because depreciation rates δ for equipment are larger than for structures (Table 4.4) and capital gains $\left(\frac{q^{*}_{iat}-q_{iat-1}}{q_{iat-1}}\right)$ are smaller for equipment than for structures, it is clear that, *ceteris paribus*, the rental price of equipment (e), c_{iet}, will be larger than the rental price of structures (s), c_{ist}. Intuitively, this means that because of the shorter life of equipment, investors require more services per year from a given dollar of investment in equipment than in structures. Accordingly, the growth of equipment will be weighted more heavily than growth in structures. And because the former grew more quickly than the latter, the aggregate capital services computed from equation (10) will grow more quickly than aggregate capital calculated as mere summation as indicated by equation (12).

4.5.3.2 Estimates of the Capital Composition Effect

The alternate user cost approaches used to derive capital services are described in Table 4.5. The five alternative approaches are all motivated either by conceptual arguments or their use in the economic literature. Given the assumptions underlying the standard multifactor productivity framework, we favour approaches 1, 2, and 3. That is, since the standard estimates presume constant returns to scale, it is appropriate to assume that the factor share earned by capital is the surplus that is measured in national accounts. After the U.S. experience, we adopt the assumption of perfect anticipations but test to see whether a moving average estimator makes much difference.

Table 4.6 presents estimates of the average annual growth rate and the volatility (standard deviation of the annual growth rate) of the composition effect for the business sector and its major constituent subsectors over the 1961-2000 period. Several results are worth noting. First, at the business sector level, the approaches 2, 4.1 and 4.2 all display the same order of size of the composition effect (roughly 1.2 percent in terms of average annual growth rate). So, imposing the identity between nominal output and total costs when the external rate of return has been used does not alter the estimate of capital composition (approach 4.1 vs. approach 4.2), but it does increase its volatility in a significant way. The approaches 1 and 3, on the other hand, provide similar average annual growth of capital composition but capital composition has a significantly lower level of volatility under the approach 1.

The composition effect reflects a) the long-term historical shift toward equipment and away from structures and b) the long-term tendency for the prices of new structures to rise more rapidly than those for equipment, causing the capital gains term subtracted in the structures rental price to be larger than that subtracted in the equipment rental price (recall that this term is omitted from the approach 2). This latter effect accentuates the

Table 4.5 Summary of Alternative Approaches of the User Cost of Capital

		Characteristics	
	Reference	Rate of Return	Capital Gains
Approach 1	Jorgenson-Siebert (1968a); Christensen-Jorgenson (1969); Fraumeni-Jorgenson (1980); BLS (1983)[a]	Internal Nominal Rate of Return from Capital Compensation Identity	Perfect Anticipations $q^*_{ait} = q_{ait}$, i.e perfectly Anticipated Capital Gains
Approach 2	Jorgenson-Siebert (1968b)	Internal Nominal Rate of Return from Capital Compensation Identity	Myopic Anticipations $q^*_{ait} = q_{ait-1}$, i.e. zero Expected Capital Gains
Approach 3	Gillingham (1980)	Internal Nominal Rate of Return from Capital Compensation Identity	Perfect Anticipations; Estimate of q^*_{ait} Using a Moving Average of Previous Asset Prices
Approach 4.1	Coen (1975); McKenzie and Thompson (1997)	External Nominal Risk Adjusted Rate of Return: the Identity Between the *ex ante* and *ex post* Rate of Returns is Not Maintained	Perfect Anticipations $q^*_{ait} = q_{ait}$, i.e. Perfectly Realized Capital Gains
Approach 4.2		External Nominal Risk Adjusted Rate of Return: the Identity Between the *ex ante* and *ex post* Rate of Returns is Maintained	Perfect Anticipations $q^*_{ait} = q_{ait}$, i.e. Perfectly Realized Capital Gains

Notes: [a] except agriculture

existing difference between equipment and structures rental prices as a result of higher economic depreciation of equipment, and thereby results in a larger rental price and cost share weight for the more rapidly growing equipment services component.

Although the estimation of the composition effect under alternate models of the user cost of capital is useful in its own right, the question on the extent to which differences in these various estimates are statistically significant still remains open. This question is addressed through the estimation of a regression model in which the dependent variable is the index of the composition effect and the right-hand variables are dummy variables for the approaches 2, 3, 4.1 and 4.2, time dummy variables for the 1961-2000 period, and interaction terms between each model and each time dummy variable. We used a fixed effect model based on a data set consisting of 16 industries, 5 approaches, and 39 years.

The results (not reported here because of the number of parameter estimates involved) indicate that statistically significant differences exist between the approach 1 and the approaches 2 and 4.2, particularly during the post 1981 period. But the level of uncertainty associated with these differences is relatively high (the parameter is significant only at 10 percent of significance). Given this result and the fact that the approaches 2 and 3 rely on stringent assumptions (a unique rate of return for the whole business sector under the approach 2 and the nominal rate of return is identical to the real rate of return under the approach 3), we adopt approaches 1 and 3 as the preferred routes on both theoretical and empirical grounds. Alternative 1 is now reported as part of the multifactor productivity program. It should be noted that this measure is also most closely related conceptually to the estimates produced by the BLS.

Table 4.6 Comparison of the Alternative Approaches of Capital Composition: Business Sector

	Approach 1		Approach 2		Approach 3		Approach 4.1		Approach 4.2	
	AAGR	Vol	AAGR	Vol	AAGR	Vol	AAGR	Vol	AAGR	Vol
Agricultural and Related Services	-0.995	0.034	-0.396	0.029	-1.057	0.036	-0.812	0.032	-0.209	0.033
Fishing and Trapping	-0.457	0.008	0.222	0.011	-0.474	0.008	-0.589	0.008	-1.027	0.014
Logging and Forestry	-0.110	0.012	-0.366	0.020	-0.156	0.013	0.095	0.012	0.181	0.026
Mining, Quarrying and Oil Well	0.145	0.007	0.479	0.006	0.225	0.007	0.234	0.006	0.212	0.010
Manufacturing	0.976	0.011	1.158	0.016	0.931	0.010	1.110	0.010	1.321	0.018
Construction	0.429	0.016	1.816	0.024	0.587	0.015	0.473	0.012	0.615	0.022
Transportation and Storage	1.629	0.011	1.158	0.012	1.782	0.011	1.473	0.011	1.362	0.014
Communication and Other Utility	1.017	0.011	0.304	0.005	1.050	0.012	1.103	0.011	0.875	0.011
Wholesale Trade	1.044	0.010	2.772	0.033	1.043	0.010	1.194	0.011	1.799	0.021
Retail Trade	1.839	0.014	1.908	0.025	1.737	0.014	1.574	0.013	1.198	0.011
Finance, Insurance and Real Estate	1.026	0.013	0.950	0.030	0.954	0.014	0.878	0.012	0.678	0.023
Business Service	1.026	0.023	2.280	0.041	1.154	0.023	1.078	0.015	2.041	0.052
Educational Service Industries	5.363	0.042	0.239	0.020	4.737	0.039	5.307	0.051	0.794	0.030
Health and Social Service	0.316	0.012	-0.013	0.026	0.304	0.012	0.397	0.009	0.813	0.029
Accommodation and Food Services	0.717	0.010	0.477	0.034	0.550	0.009	0.756	0.010	0.772	0.036
Other Service	2.121	0.022	-0.315	0.019	2.120	0.022	2.065	0.023	1.650	0.032
Business Sector	**1.16**	**0.007**	**1.242**	**0.013**	**1.167**	**0.007**	**1.202**	**0.007**	**1.229**	**0.014**

Notes: AAGR = Average annual growth rate over the 1981-2000 period; Vol = Volatility (the volatility is measured as the standard-deviation of the year-to-year growth rate of the user cost of capital);
Approach 1: internal nominal rate of return from capital compensation identity and perfectly realized capital gains;
Approach 2: internal nominal rate of return from capital compensation identity and zero expected capital gains;
Approach 3: internal nominal rate of return from capital compensation identity and expected by the moving average of previous asset prices;
Approach 4.1: external nominal risk-adjusted rate of return, perfectly realized capital gains and the identity between the *ex-ante* and *ex-post* rate of returns is not maintained;
Approach 4.2: external nominal risk-adjusted rate of return and perfectly realized capital gains, but the identity between the *ex-ante* and *ex-post* rate of returns is maintained.

4.6 Concluding Remarks

Statistics Canada started to produce multifactor productivity estimates in the late eighties. These estimates rely on a simple measure of capital services that aggregates the dollar value of all forms of capital, giving equal weights to the dollar value of all assets. This chapter explores the extent to which a more complex concept of capital services—one that recognizes asset heterogeneity—can be implemented. It has discussed the following points: a) the underpinnings of the concept of capital services and the domain of definition of capital, b) the alternate rental price of capital formula, c) the empirical analysis of these formulae along with their impact on capital composition.

An important conclusion reached by this study is that there are numerical differences in the alternate user cost formulae that are the prime candidates for adoption—but they are not statistically significant. On both empirical and conceptual grounds, the program has chosen the approach based on the internal rate of return and perfect or adaptive expectations.

The complex procedure of estimating capital service input taking into account asset heterogeneity makes a significant difference in the empirical assessment of the role of capital in the Canadian business sector's economic growth. The growth rate of a traditional capital stock measure (the directly aggregated real stock of wealth) for the Canadian business sector from 1981-2000 was 2.8 percent per year. However, capital services (based on the approach 1) grew 3.4 percent for the same period. This implies that capital services have grown 21 percent more than the capital stock. The main source of this difference is a long-term trend in the proportion of the capital stock accounted for by service-intensive short-lived equipment. This change in the measurement technique then accounts for a larger proportion of total growth than did the simple measure of capital measure.[9]

The implementation of the concept of capital services in Statistics Canada's multifactor productivity program constitutes a major step forward for Canada-U.S. comparisons of productivity growth. Using comparable methodologies underlying the estimates of output and inputs, Table 4.7 contains a breakdown of the growth of labour productivity into three components. The first arises from capital deepening—the increase in capital available per worker. The second comes from changes in the composition of the workforce—from increases in the skills of workers. The third is a residual—what is referred to as multifactor productivity. The latter captures increases in output that cannot be attributed to increases in labour or capital and captures all improvements in the production process that come from improvements in organization, more complete exploitation of economies of scale, and externalities that arise both from general improvements in knowledge and specific spillovers that allow for more efficient plant operations.

From 1981 to 2000, output per hour grew at an annual rate of 1.4% in the Canadian business sector (1.9% in the U.S.). Of the 1.4% growth rate in labour productivity in Canada, 0.3 percentage points are attributed to increases in multifactor productivity (0.9 percentage points for the U.S.), 0.6 percentage points to the contribution of capital deepening (0.7 percentage points for the U.S.) and 0.5 percentage points to changes in labour composition (0.3 percentage points for the U.S.). The contribution of capital deepening is composed of the contribution of information technology equipment, the contribution of other machinery and equipment and structures (which include inventories and land). In both Canada and the United States, most of the impact of capital

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[9] Data on output prior to 1981 were not available at the time this chapter was written.

Table 4.7 Compound Average Annual Rates of Labour Productivity Growth and the Contributions of Capital Intensity, Labour Composition, and Multifactor Productivity, Canadian and U.S. Business Sectors (percentage)

	1981-2000		1981-1988		1988-1995		1995-2000*	
	Canada	U.S.	Canada	U.S.	Canada	U.S.	Canada	U.S.
Labour Productivity Growth	1.4	1.9	1.3	1.9	1.2	1.4	1.8	2.7
Capital Deepening	0.6	0.7	0.6	0.6	0.8	0.5	0.5	1.1
Information Technology	0.4	0.6	0.3	0.5	0.4	0.4	0.5	1.0
Other Machinery and Equipment	0.1	0.0	0.2	0.0	0.1	0.0	0.2	0.1
Structures	0.1	0.1	0.1	0.2	0.3	0.1	-0.2	0.0
Labour Composition	0.5	0.3	0.5	0.3	0.6	0.4	0.3	0.3
Multifactor Productivity	0.3	0.9	0.3	0.9	-0.2	0.5	1.1	1.4

* The labour productivity estimates are those released in July 2002. Therefore, they do not include the more recent revisions implemented by both Canada and the U.S.

deepening can be attributed to increases in information technology investment. Moreover, this proportion increases over the period.

From 1981 to 1988, multifactor productivity in Canada grew at an average annual rate of 0.3% (0.9% in the U.S.). This rate, combined with the 0.6 percentage points contribution of capital deepening (0.6 percentage points in the U.S.) and the 0.5 percentage points contribution of labour composition (0.3 percentage points in the U.S.), resulted in a labour productivity growth rate of 1.3% (1.9% in the U.S.).

During the period 1980-1995, Canadian multifactor productivity declined at -0.2% per year. At the same time, the average annual contribution of capital deepening to labour productivity growth increased to 0.8 percentage points, and labour composition made a 0.6 percentage points contribution. Labour productivity, therefore, increased 1.2% (1.4% in the U.S.) per year during this period.

Information technology capital played a very important role during this period in the capital deepening process. These forms of capital contributed 0.4 percentage points per year to labour productivity growth in both Canada and the U.S. This corresponds to half of the 0.8 percentage points growth in the contribution of capital deepening in Canada (80% for the U.S.).

From 1995 to 2000, output per hour grew 1.8% per year in the business sector (2.7% in the U.S.), 0.6 percentage points faster than during the 1988-1995 period (1.3 percentage points in the U.S.). Most of the increased growth can be attributed to faster multifactor productivity growth, which surged by 1.1 percentage points (1.4 percentage points for the U.S.).

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Appendix 4.A—Tax Variables of the User Cost of Capital: Sources and Construction of the Estimates

The user cost of capital formula (4) requires the estimates of the following tax variables:

- The corporate income tax rates;
- The investment tax credit rate on corporate assets;
- The present value of capital consumption allowances;
- The property tax rate on corporate assets.

1. Corporate Income Tax Rate

1.1. Sources of the Data

We used the following variables obtained from various sources of information.

A) Taxable Income by Industry and by Province

Source A1: The data for <u>43 industries</u> and <u>10 provinces</u> based on the <u>1960 SIC-E</u> cover the period <u>1961-1987</u> (Industrial Organization and Finance Division (IOFD)) data from CANSIM, Matrices 3332, 3334, 3336, 3338, 3340, 3342, 3344, 3346, 3348, 3350, and 3358).[10]

Source A2: The data for <u>71 industries</u> and <u>10 provinces</u> based on the <u>1980 SIC-E</u> cover the period <u>1993-1996</u>. The source of these data is The Corporate Income Tax Administrative Database. (Statistics Canada, IOFD).[11]

We made the following adjustments to the data:

1) We imputed the missing data for the 1961-1972 period (e.g. taxable income of Quebec)

2) During the period 1993-1996, taxable income was negative for some provinces and industries (Taxable Income of Service Industries Incidental to Mineral Extraction for Ontario and Quebec in 1993). We set these negative values to zeros.

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[10] Table 4.A1 lists these 43 industries.

[11] Table 4. A2 lists these 71 industries.

3) No official information was available for the 1988-1992 period. We estimated the missing data (see Section B.4 step 1 in this Appendix);

4) The sources A1 and A2 are based on two different industrial classifications; therefore, a conversion to a unique industrial classification was implemented based on the 1960 SIC-E.

B) Taxable Income and Small Business Deductions by Industry (not by province)

The information on each variable was available from the following sources:

Source B1: The data for 44 industries based on the 1960 SIC-E cover the 1974-1987 period (IOFD data from CANSIM, Matrices 5326-5369).

Source B2: The data for 68 industries based on the 1980 SIC-C cover the 1988-1994 period (IOFD data from CANSIM, Matrices 4100-4167).

These sources raised the following issues:

1) The missing data for the 1961-1973 period were therefore imputed (see Section B.4 step 1 in this appendix);

2) The sources B1 and B2 are based on two different industrial classifications.

C) Combined Corporate Income Tax Rates

Source C1: The data, which cover 10 provinces for the period 1961-1988, were taken from Perry (1989), Table 16.6, p. 396.

Source C2: For the subsequent period, the data were obtained from various issues of the Canadian Tax Foundation.

The statutory corporate tax rates are available at combined federal and provincial level by firm size and sector of activity (mainly manufacturing and processing activities and nonmanufacturing and nonprocessing). These rates are available from various issues of the Canadian Tax Foundation and Perry (1989).

1.2. Construction of the Estimates

A) Overview

To estimate the Canadian corporate income tax rates for the 1961-1996 period by industry, we constructed the following variables:

a) Combined federal and provincial manufacturing and processing small business tax rates;

b) Combined federal and provincial manufacturing and processing large businesses tax rates;

c) Combined federal and provincial small businesses tax rates;

d) Combined federal and provincial large businesses tax rates;

e) The distribution of taxable income by industry across provinces;

f) The small businesses' share of taxable income.

The variables a) - f) are used as follows:

i) Construction of combined tax rates by industry: the variables a)-d) were broken-down by industry using e) as an allocation factor by industry;

ii) These combined tax rates by industry were then aggregated using the share of small and large businesses (the share is based on f).

The industrial breakdown of the tax parameter was done for the 42 industry groupings of the 1960 SIC-E. We assumed that industries from 9 to 30 constitute manufacturing and processing, while the remaining industries were considered as non-manufacturing and non-processing (see Table 4.A1).

B) The Detailed Approach

B.1) Provincial taxable income allocation

Step 1: Getting Consistent Industry Groupings Between the Sources A1and A2:

The 71 industries from source A2 are aggregated into 43 industries to get a consistent time series for taxable income by industry and province, for the 1961-1987 and 1993-1996 periods.

Step 2: Estimating the Corporate Taxable Income Share by Industry for Each Province:

Once the data on taxable income by industry and province for the periods 1961-1987 and 1993-1996 were constructed, the share of corporate taxable income by industry for each province was estimated as:

$$\alpha_{i,p,t} = \frac{Taxable\ Income_{i,p,t}}{\sum_{p=1}^{10} taxable\ Income_{i,p,t}}, \tag{A.1}$$

where

$i = 1, 2, ...42 \quad industries$

$p = 1, 2, ...10 \quad provinces$

$t = 1, 2, ...36 \quad years$

$\alpha_{i,p,t}$: the share of taxable income of the industry i in the province p in year t.

B.2) Taxable income share of small businesses by industry

Estimates of the taxable income share of small businesses by industry required the source B1 and B2.

Step 1: Getting Consistent Industry Groupings Between the Sources B1 and B2:

The source B2 based on the 1980 SIC-C was made consistent with the source B1, based on 43 industries of the 1960 SIC-E. This consistency was applied for both the taxable income and the small business deduction.

The following example for food industry illustrates how we transformed the 1980 SIC-C data to conform to the 1960 SIC-E industrial breakdown. The 1980 SIC-C is based on the concept of consolidation. In other words, the industry classification reflects the multiple activities in which an enterprise may be engaged:

$$\text{Taxable Income}^{\text{1960SIC-E}}_{\text{Food,t=88}} = \left(\frac{\text{Taxable Income}^{\text{1960SIC-E}}_{\text{Food,t=87}}}{\text{Taxable Income}^{\text{1960SIC-E}}_{\text{Agriculture,t=87}} + \text{Taxable Income}^{\text{1960SIC-E}}_{\text{Fishing\&Trapping,t=87}} + \text{Taxable Income}^{\text{1960SIC-E}}_{\text{Food,t=87}}} \right) \times \text{Taxable Income}^{\text{1980SIC-C}}_{\text{Food,t=88}} \quad \text{(A.2)}$$

The same method was applied for small business deduction.

Step 2: Calculation of the Share of Taxable Income for Small Businesses:

Taxable income for small business was not available from CANSIM data but the information exists through IOFD Custom Tabulation for the period 1988 onward.

We decided to proxy the taxable income for small business by the ratio of the small business deduction to the difference between General corporate tax rates and Small business tax rates (see below for tax estimation methodology). Therefore, the share of taxable income for small business by industry is measured as:

$$\Delta_{i,t} = \frac{Small\ Business\ Deduction_{i,t}}{Taxable\ Income_{i,t}\left(General\ tax\ rate_{i,t} - Small\ Business\ rate_{i,t}\right)} \quad \text{(A.3)}$$

B.3) Combined Federal and Provincial Income Tax Rates

Four kinds of combined federal and provincial corporate tax rates for each province are available from various issues of the Canadian Tax Foundation and Perry (1989).

- Combined Small Business rate
- Combined General Tax rate
- Combined Small Business manufacturing and processing rate
- Combined General Tax manufacturing and processing rate

B.4) Calculation of Corporate Income Tax Rates

Step 1: Calculation of the Weighted Sum of Combined Corporate Income Tax Rates:

The share of taxable income for small businesses was not available for the period 1961-1973. We used the average share of 20% estimated by Boadway and Kitchen (1980).

$$Small\ Business\ rate_{i,t} = \left(\sum_{p=1}^{10} \alpha_{i,p} . Combined\ Small\ Business\ rate_p \right)_t$$

$$General\ tax\ rate_{i,t} = \left(\sum_{p=1}^{10} \alpha_{i,p} . Combined\ General\ Tax\ rate_p \right)_t \tag{A.4}$$

The industries listed from 9 to 30 are considered as manufacturing and processing industries, and their tax rates are calculated as follows:

$$Small\ Business\ M\ \&\ P\ rate_{i,t} = \left(\sum_{p=1}^{10} \alpha_{i,p} . Combined\ Small\ Business\ M\ \&\ P\ rate_p \right)_t$$

$$General\ M\ \&\ P\ rate_{i,t} = \left(\sum_{p=1}^{10} \alpha_{i,p} . Combined\ General\ M\ \&\ P\ rate_p \right)_t \tag{A.5}$$

The missing data on taxable income by industry and by province during the period of 1988-1992 were imputed using the information available in 1987 and 1992. In particular, it is assumed that for each industry and province, the taxable income share between 1988-1992 is the average of 1987 and 1992 shares.

Step 2: Calculation of the Average Combined Federal and Provincial Corporate Tax Rates:

Finally, we calculated the average rates as follows:

- For the industries from 1 to 8 and from 31 to 43:

$$\begin{aligned} Average\ rate_{i,t} &= Small\ Business\ rate_{i,t} \times \Delta_{i,t} \\ &\quad + General\ tax\ rate_{i,t} \times \left(1 - \Delta_{i,t}\right) \end{aligned} \tag{A.6}$$

- For the industries from 9 to 30:

$$\begin{aligned} Average\ rate_{i,t} &= Small\ Business\ M\ \&\ P\ rate_{i,t} \\ &\quad \times \Delta_{i,t} + Other\ M\ \&\ P\ rate_{i,t} \times \left(1 - \Delta_{i,t}\right) \end{aligned} \tag{A.7}$$

where $\Delta_{i,t}$ is defined in A.3 as the small businesses' share of taxable income.

2. Investment Tax Credit Rate

There are various rates by type of capital used in different regions in Canada.

2.1 Sources of the Data

We used the statutory investment tax credit rates from the following source of information.

Source A: The investment tax rates for the period 1975-1996, were taken from Williamson and Lahmer (1996, p. 2,664).

The following types of capital assets have been considered:

- Qualified property;
- Qualified transportation and construction equipment;
- Qualified scientific research expenditures for Canadian-controlled private corporations;
- Qualified scientific research expenditures for non Canadian-controlled private corporations.

2.2 Construction of the Estimates

We computed the investment tax credit rate for the period 1975-1988, assuming that the investment tax credit for equipment and structures were instituted in Canada in 1975 and repealed in 1989. We reported the general rate applied in other locations in Canada.

Jung (1989) and McKenzie *et al.* (1998) suggested that the statutory investment tax credit rates could not be used because the investment tax credit is not available for all types of depreciable assets. McKenzie *et al.* (1998) calculated average effective investment tax credit rates instead of statutory rates by industry and capital cost allowance class. In addition to industry and capital cost allowance classes, Jung (1989) introduced the firm size as a third characteristic.

3. Present Value of Capital Cost Allowances

3.1 Formulae and Sources of the Data

Source A: The formulae used to calculate the present value of capital cost allowances by asset class, for the 1961-1996 period, were taken from Jung (1989), Boadway, Bruce and Mintz (1983), Boadway, Bruce and Mintz (1987), Boadway and Kitchen (1999), and Dougherty (1991). These formulae require information on the depreciable rate δ under various depreciation methods (declining-balance method and straight-line method), the corporate income tax rate τ and the interest rate i.

The formulae are :

a) For the declining-balance method:

The present value of capital cost allowances is:

- In case of full amount of capital cost in the first year:

$$z=\frac{\delta}{\left(i\times(1-\tau)+\delta\right)} \tag{A.8}$$

where:

δ = The tax allowable depreciation rate;

i = The nominal interest rate (The Government of Canada Three Month Treasury Bills);

τ = The corporate income tax rate.

- In case of half amount of the capital cost allowance for the first year:

$$z=\frac{\frac{1}{2}\times\delta}{\left(i\times(1-\tau)+\delta\right)}+\frac{1-\frac{1}{2}\times\delta}{\left(1+i\times(1-\tau)\right)}\times\left(\frac{\delta}{\left(i\times(1-\tau)+\delta\right)}\right) \tag{A.9}$$

b) For the straight-line depreciation method:

The present value of capital cost allowances is:

$$z=\frac{\delta}{i\times(1-\tau)}\times\left(1-\frac{1}{\left(1+i\times(1-\tau)\right)^{T}}\right) \tag{A.10}$$

where:

$T=$ the lifetime of the asset

c) For the 3 years straight-line depreciation method:

The present value of capital cost allowances is:

$$z=\frac{\frac{1}{4}}{\left(1+i\times(1-\tau)\right)}+\frac{\frac{1}{2}}{\left(1+i\times(1-\tau)\right)^{2}}+\frac{\frac{1}{4}}{\left(1+i\times(1-\tau)\right)^{3}} \tag{A.11}$$

3.2 Construction of the Estimates

We considered two categories of assets: structures and machinery and equipment. We, then, estimated the present value of capital cost allowances using the same method of Boadway, Bruce and Mintz (1987). This method is outlined below:

1) For building structures:

The present value of capital cost allowances was calculated as follows:

- For the 1961-1962 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.05.

- For the 1963-1966 period, the straight-line method (equation A.10) was used with δ =0.2 and T =5.

- For the 1967-1981 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.05.

- For the 1982-1996 period, the declining balance method in case of a half amount of the capital cost allowances for the first year (equation A.9) was used with δ =0.05.

2) For machinery and equipment:

The present value of capital cost allowances is:

2-1 For non-manufacturing and non-processing firms:

- For the 1961-1962 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1963-1966 period, the straight-line method (equation A.10) was used with δ =0.5 and T =2.

- For the 1967-1981 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1982-1996 period, the declining balance method in case of a half amount of the capital cost allowances for the first year (equation A.9) was used with δ =0.2.

2-2 For manufacturing and processing firms:

- For the 1961-1962 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1963-1966 period, the straight-line method (equation A.10) was used with δ =0.5 and T =2.

- For the 1967-1971 period, the declining balance method in case of a full amount of the capital cost allowances for the first year (equation A.8) was used with δ =0.2.

- For the 1972-1981 period, the straight-line method (equation A.10) was used with δ =0.5 and T =2.

- For the 1982-1996 period, the straight-line method (equation A.11) was used.

Following Boadway et al. (1987), we assumed that assets used in manufacturing and processing firms between 1970 and 1972 were allowed to be written off at the regular rate but using as a depreciation base 115 per cent of the original cost.

Boadway et al. (1987) calculated the average capital cost allowance rate by taking a weighted average capital cost allowance of rates of the most important classes. For buildings, they assumed that most investment occurred in class 3. For machinery, the most important classes were 2, 8, 10, and 29. They then calculated the present value of capital cost allowances for manufacturing and non-manufacturing and finally aggregated.[12]

4. Property Tax Rate on Corporate Assets

4.1 Sources of the Data

Source A1: The data, which cover indirect taxes on production of 167 industries for the period 1961-1995, were taken from Input Output Tables (System of National Accounts, Input-Output Division).

Source A2: The methodology on the construction of capital stock net of geometric depreciation by industry for the period 1961-1996 were described in section 4.5.2 of this chapter.

Source A2: The construction of the inventories and land series by industry for the period 1961-1998 were discussed in Tanguay (2001).

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[12] The class 3 includes the following assets: building and other structure, breakwater, dock, trestle, windmill, wharf, telephone, telegraph, or data communication equipment.

The class 2 includes the following assets: electrical generating equipment, pipeline, other than gas or oil well equipment, the generating or distributing equipment and plant of a producer or distributor of electrical energy, manufacturing and distributing equipment and plant, the distributing equipment and plant.

The class 8 includes the following assets: structure that is manufacturing or processing machinery or equipment, tangible property attached to a building and acquired solely, electrical generating equipment, portable electrical generating equipment, a rapid transit car.

The class 10 includes the following assets: automotive equipment, a portable tool, harness or stable equipment, a sleigh or wagon, a trailer, general-purpose electronic data processing equipment and systems software, a contractor's movable equipment.

The class 29 includes the following assets: property manufactured by the taxpayer, An oil or water storage tank, a powered industrial lift truck, electrical generating equipment.

4.2 Construction of the Estimates

The indirect taxes on production from Input Output Tables for the 1961-1995 period for 167 industries were aggregated to 123 industries, which is the level at which Input-Output Data and Capital Stock Data can be combined to produce productivity estimates.

The property tax rate was then calculated as follows:

$$\nu_{i,t} = \frac{\text{Indirect Taxes on Production}_{i,t}}{\left(\text{Capital Stock of Building}_{i,t} + \text{Capital Stock of Engineering} + \text{Land}_{i,t}\right)}, \qquad \text{(A.12)}$$

where,

$\nu_{i,t}$ = The property tax rate for the industry i on year t;

$\text{Capital Stock}_{i,t}$ = The nominal value of stock capital of building and engineering;

$\text{Land}_{i,t}$ = The nominal value of land.

Table 4.A1: Industrial Structure, 1960 SIC-E

Non-manufacturing and Non-processing

Total Agricultural, Forestry and Fishing
Agriculture
Forestry
Fishing and Trapping
Total Mining
Metal Mining
Mineral Fuels
Other mining
Total Transport, Communications and Utilities
Transportation
Storage
Communication
Public Utilities
Wholesale Trade
Retail Trade
Finance
Total Services
Services to Business Management
Goverment Personal and Miscellanous Services
Construction

Manufacturing and Processing

Total Manufacturing
Food
Beverages
Tobacco Products
Rubber Products
Leather Products
Textile Mills
Knitting Mills
Clothing Industries
Wood Industries
Furniture Industries
Paper and Allied Industries
Printing Publishing and Allied Industries
Primary Metals
Metal Fabricating
Machinery
Transport Equipment
Electrical Products
Non Metallic Mineral Products
Petroleum and Coal Products
Chemicals and Chemical Products
Miscellaneous Manufacturing
All Industries

Table 4.A2: Industrial Structure, 1980 SIC-E

Agricultural Industries
Service Industries Incidental to Agriculture
Fishing and Trapping Industries
Logging Industry
Forestry Services Industry
Mining Industries
Crude Petroleum and Natural Gas Industries
Quarry and Sand Pit Industries
Service Industries Incidental to Mineral Extraction
Food Industries
Beverage Industries
Tobacco Products Industries
Rubber Products Industries
Plastic Products Industries
Leather and Allied Products Industries
Primary Textile Industries
Textile Products Industries
Clothing Industries
Wood Industries
Furniture and Fixture Industries
Paper and Allied Products Industries
Printing, Publishing and Allied Industries
Primary Metal Industries
Fabricated Metal Products Industries (except Machinery and Transportation Equipment)
Machinery Industries (except Electrical Machinery)
Transportation Equipment Industries
Electrical and Electronic Products Industries
Non-Metallic Mineral Products Industries
Refined Petroleum and Coal Products Industries
Chemical and Chemical Products Industries
Other Manufacturing Industries
Building, Developing and General Contracting Industries
Industrial and Heavy (Engineering) Construction Industries
Trade Contracting Industries
Service Industries Incidental to Construction
Transportation Industries
Pipeline Transport Industries
Storage and Warehousing Industries
Communication Industries
Other Utility Industries
Farm Products Industries, Wholesale
Petroleum Products Industries, Wholesale
Food, Beverage, Drug and Tobacco Industries, Wholesale
Apparel and Dry Goods Industries, Wholesale
Household Goods Industries, Wholesale
Motor Vehicle, Parts and Accessories Industries, Wholesale
Metals, Hardware, Plumbing, Heating and Building Materials Industries, Wholesale
Machinery, Equipment and Supplies Industries, Wholesale
Other Products Industries, Wholesale
Food, Beverage and Drug Industries, Retail
Shoe, Apparel, Fabric and Yarn Industries, Retail
Household Furniture, Appliances and Furnishings Industries, Retail
Automotive Vehicles, Parts and Accessories Industries, Sales and Service
General Retail Merchandising Industries
Other Retail Store Industries
Non-Store Retail Industries
Deposit Accepting Intermediary Industries
Consumer and Business Financing Intermediary Industries
Investment Intermediary Industries
Insurance Industries
Other Financial Intermediary Industries
Real Estate Operator Industries (except Developers)
Insurance and Real Estate Agent Industries

Table 4.A2: Industrial Structure, 1980 SIC-E – *concluded*

Business Service Industries
Educational Service Industries
Health and Social Service Industries
Accommodation Service Industries
Food and Beverage Service Industries
Amusement and Recreational Service Industries
Personal and Household Service Industries
Membership Organization Industries
Other Service Industries

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Appendix 4.B—Aggregation of Capital Services

This appendix provides a formal treatment of the construction of the aggregate capital stock and capital services over 23 categories of fixed reproducible assets in addition of land and inventories. For illustration purposes, we aggregate in two stages: first, we grouped these 23 assets into three asset classes—information technology, other machinery and equipment, structures including land and inventories. These groupings may be useful for analytical needs such as those related to the new economy (see Chapter 1 for example). In the second stage, the three asset classes are aggregated into a broader index of "total capital services." It is this broad index of total capital services that is appropriate for the aggregate production function.

The various methods of aggregation have been much discussed elsewhere and we shall not elaborate on them here (see Diewert 1980a). Suffice it to say, we use the Fisher index due to its exact aggregation properties.

Asset Class Indexes

We begin by defining four variables that are relevant for productivity analysis for each asset class j, where j represents the following three asset classes: information technology, other machinery and equipment and structures.[13] $\tilde{K}_t^j$ is an index of capital services; $\hat{K}_t^j$ is an index of capital stock; K_t^j is a simple sum of capital stock; and q_t^j is an index of quality, all for asset class j at time t.

The quantity index of capital services for asset class j is defined as the Fisher aggregate of the different assets that comprise the asset class:

$$\tilde{K}^j_{t/t-1} = \sqrt{\sum_{a\in A} v_{at-1}\left(\frac{K_{at}}{K_{at-1}}\right)\cdot \sum_{a\in A} v_{at}\left(\frac{K_{at}}{K_{at-1}}\right)} \tag{B.1}$$

where A is the set of all assets that belong to asset class j and weights v_{at} and v_{at-1} are rental cost shares defined as:

$$v_{at} = \frac{c_{at}K_{at-1}}{\sum_{a\in A} c_{at}K_{at-1}} \equiv \frac{V_{at}}{V_t^j} \text{ and } v_{at-1} = \frac{c_{at-1}K_{at-1}}{\sum_{a\in A} c_{at-1}K_{at-1}} \equiv \frac{V_{at-1}}{V_{t-1}^j}$$

---

[13] These asset classes comprise the non-residential assets listed in Table 4.4, four residential assets, land and inventories.

where V_t^j and V_{t-1}^j are the nominal values of capital services in class j in year t and $t-1$.

The rental cost index of capital services for asset class j in year t is given by:

$$c_t^j = \frac{V_t^j}{\tilde{K}_t^j}$$

Similarly, the quantity index of capital stock for asset class j is given by:

$$\hat{K}_{t/t-1}^j = \sqrt{\sum_{a \in A} w_{at-1} \left(\tfrac{K_{at}}{K_{at-1}}\right) \cdot \sum_{a \in A} w_{at} \left(\tfrac{K_{at}}{K_{at-1}}\right)} \tag{B.2}$$

where weights are now value shares of the capital stock defined as:

$$w_{at} = \frac{q_{at} K_{at-1}}{\sum\limits_{a \in A} q_{at} K_{at-1}} \equiv \frac{W_{at}}{W_t^j} \text{ and } w_{at-1} = \frac{q_{at-1} K_{at-1}}{\sum\limits_{a \in A} q_{at-1} K_{at-1}} \equiv \frac{W_{at-1}}{W_{t-1}^j}$$

where q_{at} is the price of the asset, W_t^j and W_{t-1}^j are the nominal values of capital stock in class j in year t and $t-1$.

The price index of capital stock for class j is defined as:

$$q_t^j = \frac{W_t^j}{\hat{K}_t^j}$$

We also define an alternative measure of the capital stock for class j assets as the simple sum of the constant dollar stocks:

$$\bar{K}_t^j = \sum_{a \in A} K_{at} \, .$$

We define the index of capital quality for class j as:

$$\tilde{K}_t^j = \Delta_t^j \cdot \bar{K}_t^j \tag{B.3}$$

which can be rewritten as

$$\ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) = \ell n\left(\frac{\tilde{K}_t^j}{\tilde{K}_{t-1}^j}\right) - \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) \tag{B.4}$$

Growth in the index of capital quality equals the difference in the growth rate of capital services and a simple sum of the capital stock. Note that capital quality for class j in (B.3) is indexed by time and varies in (B.4), while asset-specific capital quality is a constant. This reflects the specific definition of capital quality in this context. As relative rental prices changes, firms substitute between assets within each asset class and this capital-capital substitution is what we refer to as growth in capital quality.

Aggregate Indexes

We now define similar variables at higher levels of aggregation. Fixed reproducible capital is an aggregate over the three classes of assets listed above, while total capital is an aggregate over the same three classes. Both calculations are based on the methodology that follows and only differ on which components are included. The index of aggregate capital services is defined as the Fisher aggregate of the components as:

$$\tilde{K}_{t/t-1} = \sqrt{\sum_j v^j_{t-1}\left(\frac{\tilde{K}_{jt}}{\tilde{K}_{jt-1}}\right)\cdot\sum_j v^j_t\left(\frac{\tilde{K}_{jt}}{\tilde{K}_{jt-1}}\right)} \tag{B.5}$$

where the weights are again value shares of capital income

$$v^j_t = \frac{c^j_t\tilde{K}^j_{t-1}}{\sum_j c^j_t\tilde{K}^j_{t-1}} \equiv \frac{V^j_t}{V_t} \text{ and } v^j_{t-1} = \frac{c^j_{t-1}\tilde{K}^j_{t-1}}{\sum_j c^j_{t-1}\tilde{K}^j_{t-1}} \equiv \frac{V^j_{t-1}}{V_{t-1}}$$

where V_t and V_{t-1} are the nominal values of capital income for all asset classes.

The rental cost index of capital services for aggregate capital is:

$$c_t = \frac{V_t}{\tilde{K}_t}$$

Similarly, the aggregate quantity index of capital stock is given by:

$$\hat{K}_{t/t-1} = \sqrt{\sum_j w^j_{t-1}\left(\frac{\hat{K}^j_t}{\hat{K}^j_{t-1}}\right)\cdot\sum_j w^j_t\left(\frac{\hat{K}^j_t}{\hat{K}^j_{t-1}}\right)}$$

where weights are again value shares of the aggregate capital stock:

$$w^j_t = \frac{q^j_t\hat{K}^j_{t-1}}{\sum_j q^j_t\hat{K}^j_{t-1}} \equiv \frac{W^j_t}{W_t} \text{ and } w^j_{t-1} = \frac{q^j_{t-1}\hat{K}^j_{t-1}}{\sum_j q^{t-1}_j\hat{K}^j_{t-1}} \equiv \frac{W^j_{t-1}}{W_{t-1}}$$

The price index of the aggregate capital stock index is

$$q_t = \frac{W_t}{\hat{K}_t}$$

Finally, we have the simple sum of the aggregate capital stock:

$$\bar{K}_t = \sum_j K_t^j .$$

We can now define the quality index for aggregate capital. Using the same definition as in equation (B.3) above, we have:

$$\tilde{K}_t = \Delta_t \cdot \bar{K}_t .$$

which implies that the growth in the quality of aggregate capital is:

$$\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) = \ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) - \ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right) \tag{B.6}$$

It is useful to rewrite (B.6) to provide more economic intuition as

$$\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) = \left[\ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) - \ell n\left(\frac{\hat{K}_t}{\hat{K}_{t-1}}\right)\right] + \left[\ell n\left(\frac{\hat{K}_t}{\hat{K}_{t-1}}\right) - \ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right)\right] \tag{B.7}$$

The first set of brackets measures the difference in the growth rates of capital services and the capital stock index. This reflects substitution between assets in response to rental price changes. The term in the second set of brackets measures the difference in growth rates between the capital stock index and the simple sum of capital stocks. This is to highlight the difference between our measure and the simple sum that has been used in other studies. As should be clear from these equations, simply summing constant dollar quantities will lead to a biased index since it does not account for changes in relative prices.

As a final step, it is useful to decompose growth in the aggregate index of capital services into several components that reflect changes both between and within asset classes. Applying capital income shares to equation (B.4) and summing over asset classes we get:

$$\sum_j \bar{v}_t^j \ell n\left(\frac{\tilde{K}_t^j}{\tilde{K}_{t-1}^j}\right) = \sum_j \bar{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j \bar{v}_t^j \ell n\left(\frac{\bar{K}_t^j}{\bar{K}_{t-1}^j}\right) \tag{B.8}$$

From (B.5) and (B.6) we have:

$$\sum_j \bar{v}_t^j \ell n\left(\frac{\tilde{K}_t^j}{\tilde{K}_{t-1}^j}\right) = \ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) + \ell n\left(\frac{\bar{K}_t}{\bar{K}_{t-1}}\right) \tag{B.9}$$

Combining the above two equations, the growth in aggregate quality may be expressed as:

$$\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right) = \sum_j \overline{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j \overline{v}_t^j \ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right) - \ell n\left(\frac{\overline{K}_t}{\overline{K}_{t-1}}\right)$$

Substituting this into equation (B.6), and adding and subtracting $\sum_j \overline{w}_t^j \ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right)$ yields the following decomposition of the growth in aggregate capital services:

$$\begin{aligned}\ell n\left(\frac{\tilde{K}_t}{\tilde{K}_{t-1}}\right) &= \left[\ell n\left(\frac{\Delta_t}{\Delta_{t-1}}\right)\right] + \left[\ell n\left(\frac{\overline{K}_t}{\overline{K}_{t-1}}\right)\right] \\ &= \sum_j \overline{v}_t^j \ell n\left(\frac{\Delta_t^j}{\Delta_{t-1}^j}\right) + \sum_j (\overline{v}_t^j - \overline{w}_t^j) \ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right) + \sum_j \overline{w}_t^j \ell n\left(\frac{\overline{K}_t^j}{\overline{K}_{t-1}^j}\right)\end{aligned} \tag{B.10}$$

This expression, which represents aggregate quality change, is a bit complicated, but each piece has a specific economic interpretation. We refer to the first parentheses as the "within quality effect," which measures substitution and capital quality growth within distinct asset classes. The second parentheses represent the "between quality effect," which measures substitution between distinct asset classes. The third parentheses represents an "index quality effect," which captures the growth rate of the capital index. The last term is the "capital accumulation effect," which measures raw capital accumulation.

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5

Unit Labour Costs and the Competitiveness of Canadian Businesses

MUSTAPHA KACI AND JEAN-PIERRE MAYNARD

5.1 Introduction

Unit labour cost is the wage expense that a business incurs per unit of output. It increases when the wage rate rises more rapidly than labour productivity. Because it reflects both productivity gains and wage inflation, the growth of unit labour cost (ULC) is related to businesses' long-term performance. Given the importance of international competitiveness, controlling wage costs has always been a major objective for Canadian businesses.

In this study, we begin by reviewing the characteristics of the ULC in the business sector, and we answer the following questions: What exactly is this indicator? How is it measured? We then explain the different mechanisms by which the ULC serves as a leading indicator of the evolution of costs in businesses. For this purpose, we compare the ULC indicator to a more complete measure of variable costs, which also include the costs of raw materials, energy and subcontracted services. The evolution of the partial measure, the ULC, is compared to the evolution of variable costs in general for the business sector and for manufacturing in Canada during the period 1961-1997. This leads us to examine trends in the evolution of ULCs in the Canadian business sector during the past four decades. Finally, the ULC is used to analyse the competitiveness of the Canadian manufacturing sector in relation to its U.S. counterpart for the past decade. For manufacturing industry groups at the two-digit level, the relationship between export growth and the relative unit cost is also examined.

5.2 Definition and Measurement of the Unit Labour Cost

To better grasp the concept of the unit labour cost, it is useful to situate it in the context of the different costs involved in production. By briefly enumerating the different types of costs that a business faces, we can better situate the concept of ULC. Appendix 5.A provides an overview of the concepts relating to production costs.

The unit (or average) labour cost is the compensation of labour in nominal terms per unit of output:

$$\text{Unit labour cost} = \frac{\text{Total labour compensation}}{\text{Real output}} \qquad (1)$$

Thus, for a business that manufactures motorcycles, the unit labour cost for a given period can be calculated if we know the payroll of its employees and the number of units produced. For example, if this business produces ten motorcycles per hour and has 500 employees earning an average of $20 per hour the ULC (cost of labour per unit produced) will be $1,000 (500 X $20/10).

At the aggregate level, output can only be measured in terms of value, that is, in dollars, and not in terms of physical volume (quantity produced), since it is not possible to put telephone services, vehicles and chairs on the same footing without using the value of each. Because of the vast number of goods and services produced and the difficulty of finding a common unit of measurement for all of them, output is measured in monetary terms.

To make comparisons of real output from one year to another, it is also necessary to eliminate the effect of a general movement of prices. Thus, the change in quantities produced is estimated by eliminating general price inflation, that is, by calculating output in period *t* at the price of another period, usually a previous year. This measure gives an indication of the real increase in output, an increase not associated with price changes.

The unit labour cost is a ratio: its value increases with the increases in the numerator—labour compensation—or decreases with increases in the denominator—real output. Thus far, we have dealt with wage costs only at the level of the individual business. Costs considered for businesses in general are nothing other than an aggregation of the individual costs of each business. Thus, the ULC for the business sector as a whole is defined as follows:

$$\text{ULC} = \frac{\text{Total compensation for all jobs}}{\text{Real value-added}} \qquad (2)$$

For the business sector as a whole, the concept of unit cost usually refers to the ratio between total compensation for all jobs and real value-added.

When calculating the unit cost for a business, real value-added is used as a measure of output. It reflects what is added by the primary factors: labour and capital. The value-added of a business consists of its gross output (mainly the amount of its sales) minus its purchases of goods and services from other businesses in order to produce that output. The aggregation of the value-added of all businesses provides a figure representing the total output of the business sector as a whole. The value-added of the business sector is also known as gross domestic product (GDP).

Total compensation for all jobs represents the total amount paid by businesses to their employees**.** It includes all payments in cash or in kind paid in Canada by businesses to workers in compensation for the services that they have rendered. This includes wages, salaries and supplementary labour income of paid workers, as well as an implicit labour income for self-employed workers.

5.3 The ULC as a Concept Related to Labour Productivity

The ULC of the business sector is an indicator that summarizes the evolution of labour productivity and wage compensation. The link between productivity—a measure of the improvement of the efficiency of the production process—and the unit labour cost may be shown by dividing the numerator and the denominator in the usual formula by the number of hours worked for all jobs (h):

$$ULC = \frac{\dfrac{\text{Total compensation for all jobs}}{h}}{\dfrac{\sum \text{real value-added}}{h}} = \frac{\text{Hourly compensation}}{\text{Labour productivity}} = \frac{HC}{LP} \qquad (3)$$

Thus, the average unit cost of labour is equivalent to the ratio between hourly compensation (HC) and labour productivity (LP). It should be noted that value-added in real terms is calculated using a double deflation approach, by means of which real intermediate inputs are subtracted from real gross output.

Economic studies in the business sector are less concerned with the level of unit labour costs than with how these costs evolve between two periods. The goal is to evaluate the degree of control over labour costs by analysing their annual growth rates. We can obtain an approximate[1] picture of the change in ULCs using the following formula:

$$\Delta ULC = \Delta HC - \Delta LP \qquad (4)$$

In other words,

% change in ULC = % change in hourly compensation - % change in labour productivity.

On the basis of this formulation, it is apparent that if hourly compensation increases faster than the productivity level, ULC will increase (Case 1). Conversely, if the labour productivity level increases faster than hourly compensation, ULC will decrease (Case 2). Furthermore, if hourly compensation increases at a fast pace and the increase in labour productivity declines at the same time, ULC will undergo two upward impulses (Case 3). Lastly, ULC will remain invariable if both its components evolve at the same pace (Case 4). These four cases are illustrated in Table 5.1 below:

Table 5.1 Behaviour of Unit Labour Costs in Response to Changes in Labour Productivity (LP) and Hourly Compensation (HC)

Case	Δ HC	Δ LP	Δ ULC
1	3%	2%	1%
2	4%	6%	-2%
3	4%	-2%	6%
4	3%	3%	0%

In summary, the evolution of the ULC is a residual between the evolution of hourly compensation and that of labour productivity.

5.4 Evolution of ULC in the Past Twenty Years

5.4.1 At the Aggregate Level

Since 1979, the Canadian business sector has experienced sizable variations in the ULC and its main components: hourly compensation and labour productivity. The following figure shows how it evolved between 1979 and 2000.

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[1] Arithmetic growth rates are not completely additive. An exact relationship can be obtained using logarithmic changes.

Figure 5.1 Change in Unit Labour Costs, Hourly Compensation and Productivity in the Business Sector: 1979-2000

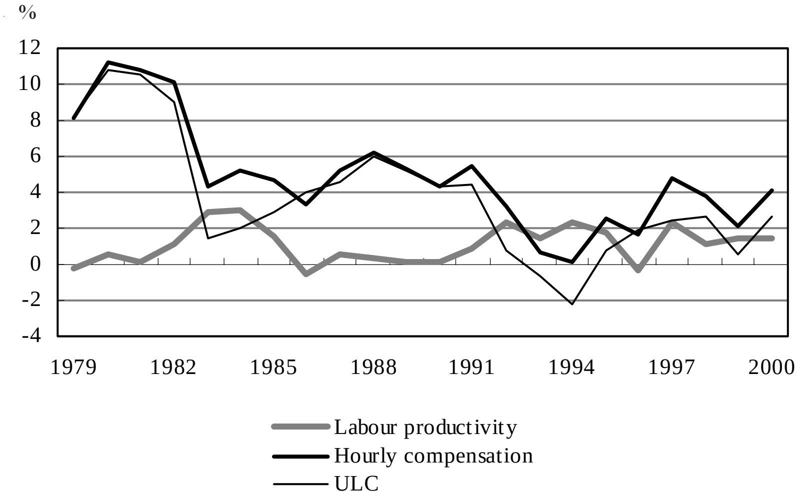

Figure 5.2 Unit Labour Costs by Sector, Average Annual Growth Rates, 1961-2000

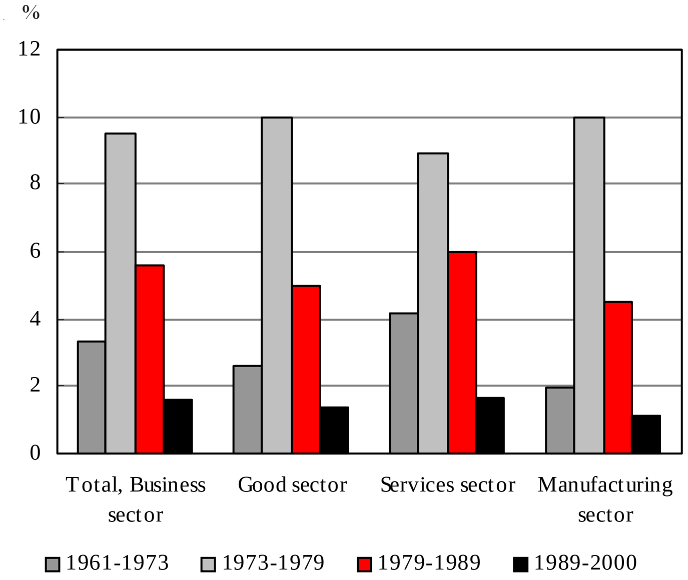

Table 5.2 Unit Labour Costs, Hourly Compensation and Labour Productivity by Major Sector, 1961-2000

	1961-2000	1961-1973	1973-1979	1979-1989	1989-2000
			% change		
Business Sector					
Labour Productivity	2.0	3.7	1.5	1.0	1.4
Hourly Compensation	6.4	7.2	11.1	6.6	3.3
Unit Labour Costs	4.3	3.3	9.5	5.6	1.6
Goods Sector					
Labour Productivity	2.6	4.7	2.07	1.5	1.8
Hourly Compensation	6.7	7.5	12.2	6.6	3.2
Unit Labour Costs	4.0	2.6	10.0	5.0	1.4
Service Sector					
Labour Productivity	1.5	2.6	1.2	0.7	1.3
Hourly Compensation	6.2	6.9	10.3	6.7	2.9
Unit Labour Costs	4.6	4.2	8.9	6.0	1.6
Manufacturing Industries					
Labour Productivity	2.7	4.2	2.1	2.2	2.0
Hourly Compensation	6.4	6.2	12.3	6.8	3.2
Unit Labour Costs	3.6	2.6	10.0	4.5	1.1

As may be seen from Figure 5.1, between 1979 and 1982, businesses saw their ULC grow at double-digit annual rates. Subsequently, the unit labour cost grew less rapidly. It grew at an average rate of 3.6% between 1983 and 1992. Following the 1990-1991 recession, the ULC rose moderately starting in 1992, at an average rate of 1.0% per year.

In the business sector as a whole, the average growth of unit costs was limited to 1.6% during the period 1989-2000, compared with 5.6% between 1979 and 1989 (Table 5.2 and Figure 5.2). The average increase in hourly compensation slowed to 3.3% during the past decade as compared with 6.6% during the 1980s, and this, combined with the slight increase in labour productivity (1.4% per year), is largely responsible for the improved performance of Canadian businesses with respect to labour costs during the period 1989-2000.

During the past decade, the ULC increased at roughly the same rate in the two major components of the business sector: the goods sector experienced an annual rate of increase of 1.4% and the services sector, 1.6%.

Between 1989 and 2000, labour productivity grew more rapidly in the goods sector, at 1.8% (compared with 1.3% in the services sector), while the increase in hourly compensation in the goods sector increased by 3.2%, compared with 2.9% in the services sector. Thus, during this period, the relatively more modest increase in unit labour costs in the goods sector was largely due to the superior performance of labour productivity in that sector.

In manufacturing, the average annual increase in ULCs dropped, going from 4.5% per year during the period 1979-1989 to 1.1% between 1989 and 2000. This marked decline is mainly attributable to slower wage growth in manufacturing, namely 3.2% compared with 6.8% during the 1979-1989 cycle. During this time, labour productivity grew at almost the same rate during the two periods, namely 2.2% and 2.0% respectively.

The evolution of ULCs is a crucial factor in businesses' long-term performance, since it reflects both productivity gains and wage inflation. During the past four decades, the ULC grew at an average of 4.3% per year. If we divide the period from 1961 to 2000 into four sub-periods, namely 1961 to 1973, 1973 to 1979, 1979 to 1989 and 1989 to 2000, we observe that the average annual growth rate of the ULC in the business sector was much lower during the last sub-period (1.6% compared with 3.3%, 9.5% and 5.6% for the previous sub-periods). The main factor in the slower growth rate of ULC was the more modest rate of increase in hourly compensation, which declined from 6.6% in the 1980s to 2.5% between 1992 and 2000.

Since the last recession in 1991-1992, several factors have combined to create conditions more favourable to slower price and cost inflation. These include reduced pressure from demand,[2] corporate restructuring, which has resulted in major changes in the composition of the workforce; and much more modest wage increases granted when collective agreements were renewed.

5.4.2 Among Industries, Major Disparities Exist in Labour Costs

Table 5.3 shows the average annual growth rates of productivity, hourly compensation and the ULC by industry group for the past two decades: 1979-1989 and 1989-2000. Depending on the sub-period, the growth rates of unit labour costs varied considerably from one industry to another. In particular, the cost performance of industry groups during the 1990s ranged between -1.6% in agriculture and 5.0% in health care services and social services.

During the same period, agriculture registered the largest labour productivity gain (5.2%), while the largest drop was in health care services and social services (-2.9%). Disparities with respect to hourly compensation were relatively minor, with the largest observed in finance, insurance and real estate (4.5%) and the smallest in retail trade (1.7%). During the past decade, then, unit labour cost disparities among industries were mainly attributable to differences in productivity, since the increase in hourly compensation had less inter-industry variability.

5.5 The Link Between the ULC and a Broader Indicator: The Variable Cost Per Unit of Output

The cost of labour is one of the main business expenses and this is why the evolution of labour costs is often studied. However, if only labour is considered when analysing the evolution of businesses' production costs, this can give an inaccurate picture of upward pressures on costs. Those pressures also come from changes in other variable costs.

While labour costs are a major component of a business's variable production costs, they are not the only ones. Other expenses that enter into a business's variable costs include raw materials, energy and subcontracted services.

Table 5.4 gives an idea of the costs of each input as a proportion of the real gross output of the business sector and the manufacturing sector in 1997.

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[2] Excess demand is reflected in movements in the price level that put pressure on ULCs.

Table 5.3 Average Annual Growth Rates of Labour Productivity, Hourly Compensation and Unit Labour Cost by Industry Group - 1979-2000

Industry	Labour Productivity		Hourly Compensation		Unit Labour Cost	
	1979-1989	1989-2000	1979-1989	1989-2000	1979-1989	1989-2000
				%		
Agriculture and Related Services	2.8	5.2	6.1	3.5	3.1	-1.6
Fishing and Trapping	-1.2	-0.9	5.1	2.6	6.4	3.5
Logging and Forestry	3.8	-0.2	6.5	3.8	2.5	4.0
Mining, Quarrying and Oil Wells	0.2	1.6	7.0	3.1	6.7	1.5
Manufacturing Industries	2.2	2.0	6.8	3.2	4.5	1.1
Construction	0.3	-0.3	6.0	2.2	5.6	2.6
Transportation and Storage	0.8	1.6	4.9	2.5	4.0	0.9
Communication and Other Utilities	1.6	2.3	5.6	2.0	4.0	-0.4
Wholesale Trade	4.6	1.9	8.5	2.0	3.7	0.1
Retail Trade	0.7	1.8	6.5	1.7	5.8	-0.1
Finance, Insurance and Real Estate	-1.1	2.7	7.2	4.5	8.5	1.7
Business Services	0.5	0.0	7.2	3.9	6.7	3.9
Private Educational Services	-3.3	-0.7	1.4	4.1	4.8	4.8
Private Health Care and Social Services	-2.6	-2.9	5.2	2.0	8.0	5.0
Accommodation and Food Services	-1.4	0.2	6.2	2.3	7.8	2.2
Other Service Industries	1.3	-0.4	6.5	2.9	5.2	3.3

Table 5.4 Costs of Each Input as a Proportion of Output, 1997

	Business Sector	Manufacturing Sector
	(percentage)	
Capital	18.2	14.0
Labour	29.9	18.4
Energy	2.7	2.5
Raw Materials	27.7	51.6
Services Purchased	21.5	13.5

Table 5.4 shows that wages and raw materials are the main variable costs in the business and manufacturing sectors. All things being equal, increases in wages and the prices of raw materials should therefore have a sizable impact on variable costs of production in these sectors.

Capital is not included in variable costs, since businesses cannot modify their production equipment in the short run by purchasing and installing new machinery. Capital is therefore considered a fixed cost in the short run. On the other hand, labour constitutes a variable cost, since a business can hire or lay off workers if the demand for its products changes suddenly.

A more complete measure of unit (or average) variable costs should take account of all inputs that may vary in the short run, including labour costs. It is therefore useful to define a broader measure of variable costs, which in this study will be called the unit variable cost (UVC), and to examine its relationship with the ULC.

The unit variable cost would thus be an indicator serving to measure all variable costs of inputs used in the short-term production process. This is a broader measure that could explain how price movements can differ from one industry to another, even if wage increases in those industries are similar.

Figure 5.3 Unit Labour Costs and Unit Variable Costs in Manufacturing Sector, 1961-1997

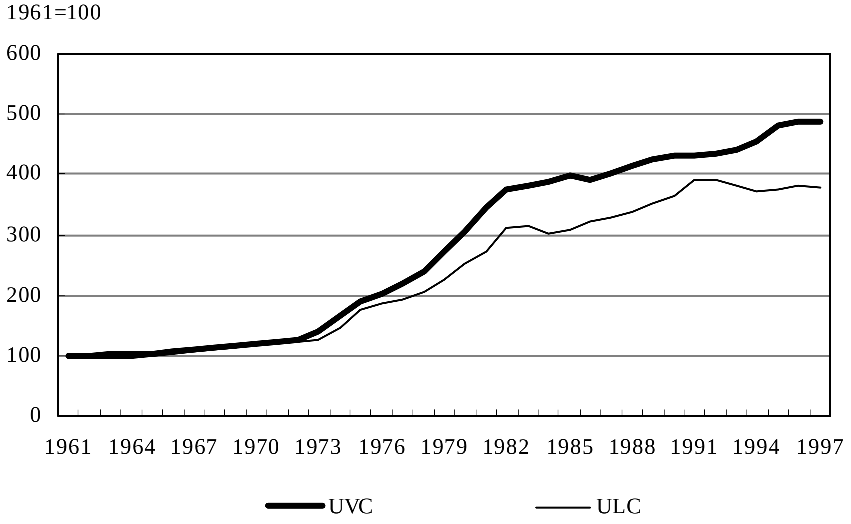
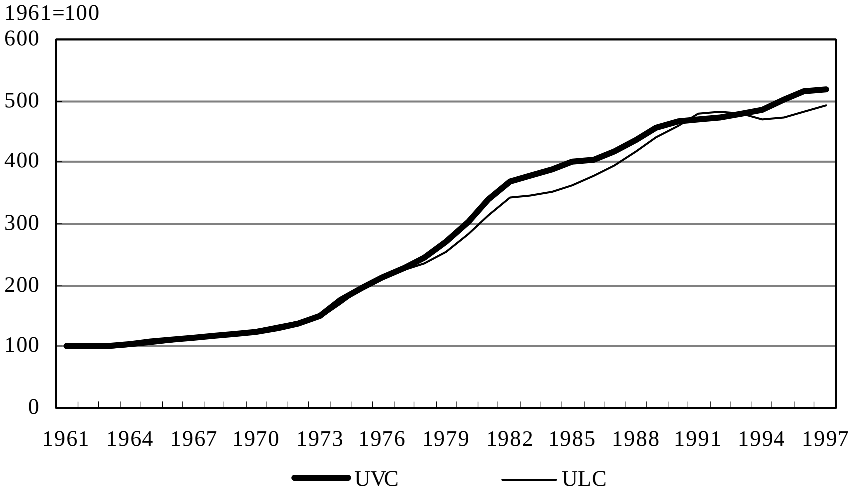


Figure 5.4 Unit Labour Costs and Unit Variable Costs in Business Sector, 1961-1997



The unit variable cost of production (UVC) represents the average variable cost of one unit of gross output. It is the ratio between all variable costs and real gross output,[3] and thus:

$$\text{UVC} = \frac{\text{Cost of labour} + \text{Cost of energy} + \text{Cost of raw materials} + \text{Cost of services}}{\text{Real gross output}} \qquad (5)$$

5.5.1 Relationship Between the Two Indexes

The relationship between the ULC and the UVC in the business sector and the manufacturing sector in Canada is shown in Figures 5.3 and 5.4, which illustrate, in the form of indexes, how the ULC and the UVC evolved during the period 1961-1997.

An examination of these two figures reveals that apart from the period from 1991 to 1993, when the ULC and the UVC diverge somewhat, the two indexes evolve along similar lines throughout the period 1961-1997. In other words, they both move upward and downward at the same time, which suggests a strong correlation between the two trends.

The coefficient of correlation[4] of 0.99 estimated between the two unit cost measures, both for the business sector as a whole and for manufacturing, confirms the link illustrated in the two figures.

Cost measures are usually calculated in the form of indexes; but they are also often expressed in terms of growth rates. Fluctuations in the ULC and the UVC in the business sector and in manufacturing over the period from 1961 to 1997 are presented in Figures 5.5 and 5.6.

While the ULC and the UVC diverge for particular periods, these two figures reveal that the two measures exhibit almost identical trends for the study period as a whole.

Table 5.5 shows the average annual growth of the ULC and the UVC in the business sector and in manufacturing during the period 1961-1997. As may be seen, the two measures in the business sector increased at an almost identical rate throughout the period 1961-1997, that is, at an average annual rate of 4.7% for the UVC and 4.5% for the ULC.

During the period prior to 1973, the ULC and the UVC in the business sector increased on average at the same rate, that is, at an average annual rate of 3.3%. Starting in 1973, divergences began to appear between the growth rates of the UVC and the ULC. The ULC grew slightly more slowly than the UVC, except between 1983 and 1992 when the opposite occurred.

In the business sector, the UVC grew at annual rates averaging 10.6% during the period 1973-1979 and 8.5% during the period 1979-1983. In comparison, the ULC grew by respectively 9.5% and 7.9% during the same periods. The fact that the UVC grew more rapidly than the ULC between 1973 and 1983 has to do with exceptional events that marked that period, such as the substantial increases in the price of imported oil in 1973-1974 and 1979-1980. As a result of those increases, energy costs in the business sector rose 21.3% during the period 1973-1979 and by 15.0% between 1979 and 1983.

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[3] When calculating the UVC, gross output in real terms is the relevant measure to use, since it includes all inputs, including labour and capital.

[4] The coefficient of correlation is calculated for the period 1961-1997.

Figure 5.5 Unit Labour Costs and Unit Variable Costs in Business Sector, 1962-1997

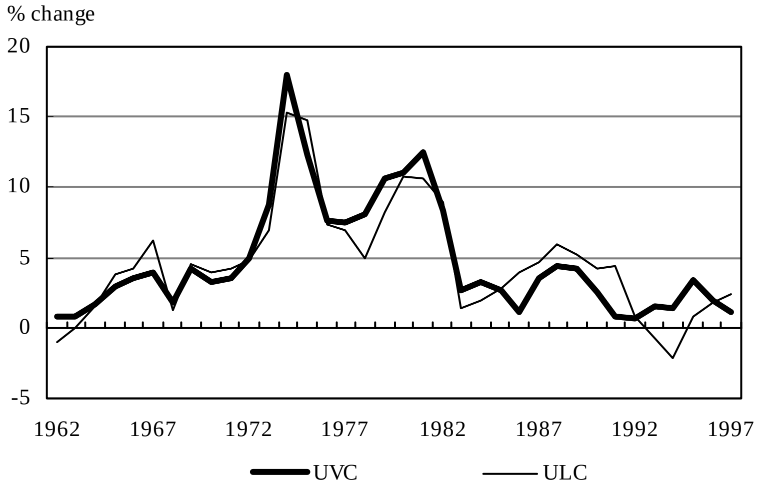

Figure 5.6 Unit Labour Costs and Unit Variable Costs in Manufacturing Sector, 1962-1997

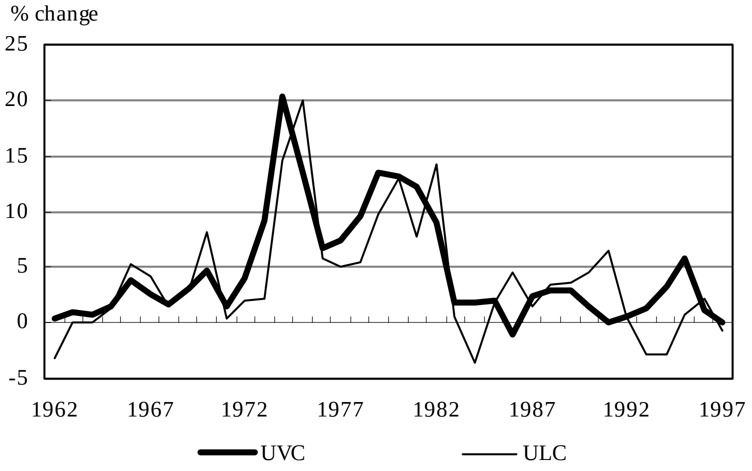

Table 5.5 Unit Labour Costs and Unit Variable Costs in the Business and Manufacturing Sectors, Average Annual Growth for Different Sub-periods Between 1961 and 1997

	Business Sector		Manufacturing Sector	
	UVC	ULC	UVC	ULC
	% change			
1961-1997	4.7	4.5	4.5	3.8
1961-1973	3.3	3.3	2.8	2.0
1973-1979	10.6	9.5	11.7	10.0
1979-1983	8.5	7.9	9.0	8.7
1983-1992	2.6	3.8	1.5	2.5
1992-1997	1.9	0.4	2.3	-0.7

These sizable increases drove up production and transportation costs for almost all products during these two periods.

Table 5.5 also shows that the average annual growth of the ULC in the business sector was greater than that of the UVC between 1983 and 1992 (3.8% versus 2.6%). This turnaround would appear to be largely attributable to a 9.0% drop in the cost of raw materials in 1991 and the collapse of oil prices in 1986 (-14.0%). During the period 1983-1992, the costs of raw materials and energy in the business sector increased respectively 3.5% and 2.3% annually, compared with an average annual growth rate of 6.4% for the cost of labour.

For the period 1992-1997, the UVC and the ULC grew more moderately than in previous periods. The average annual growth of the UVC was 1.9%, while that of the ULC was a mere 0.4%.

The manufacturing sector experienced a situation similar to that of the business sector in the evolution of the ULC and the UVC during the same periods, except for the period 1961-1973 when the UVC grew on average more rapidly than the ULC (2.8% per year versus 2.0%).

Clearly, the UVC is a more accurate indicator of short-term pressures on costs, but the ULC is still useful because of its strong correlation with the UVC and its timeliness. Statistics Canada's quarterly ULC is released two months after the end of the reference quarter, whereas the UVC cannot be measured until roughly 30 months later.

Given the strong positive correlation (very nearly 1) between the two cost measures and the greater timeliness of the ULC quarterly data, one of the advantages of the ULC indicator is that it can warn of pressures on costs in the business sector and in manufacturing much earlier than could be done with the UVC.[5]

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[5] Other variants of variable costs can also be measured. Along the same lines, Dion and Fairclough (2000) recently looked at certain variants of unit costs. In their study, they present other measures of unit costs for the tradable goods sector and compare them to the ULC index for the manufacturing sector over the period 1961-1996. These authors find that the estimated indexes of unit labour costs in the tradable goods sector have profiles that are fairly similar to those of the ULC index for the manufacturing sector. The latter index could, to some extent, adequately represent the evolution of unit labour costs in the tradable goods sector.

5.6 The ULC as an Indicator of the Cost Competitiveness of the Business Sector

The concept of labour cost can provide an indicator of how competitive Canadian businesses are in relation to their foreign counterparts. To adequately exploit economies of scale, Canadian businesses are in fact increasingly dependent on foreign markets. What is meant by competitiveness? This often-used concept is frequently subject to controversy.

In general, competitiveness refers to the ability of a business, a group of businesses or a country to compete internationally. For the purposes of our analysis, we have adopted a definition focusing solely on costs. The business sector, for example, will be competitive if its unit costs are equal to or less than those of its competitors. Under these terms, competitiveness is determined by two different factors: Unit costs of production and the exchange rate.

Unit costs of production:

As explained above, when a business's unit costs—notably labour costs—increase, this generally results in an increase in the price of its products. All things being equal, those products then sell for more than the products of its competitors.

The exchange rate:

The exchange rate makes it possible to compare prices and costs between two countries in a common currency. Exporting businesses must frequently deal with changes in the exchange rate, since these changes affect the price of goods sold abroad. In the case of a depreciating Canadian dollar, Canadian products become relatively cheaper on external markets. Foreign products become more expensive in Canadian markets.

These two components may evolve differently and either offset or reinforce each other. For example, if the Canadian dollar loses value against the U.S. dollar and if a business makes productivity gains that translate into lower unit costs of production, then the price of its products for export will be subject to two downward pressures, which should enable it to sell more on the U.S. market. As a result, it is in a better position to export.

If we want to assess the competitive position of Canadian businesses in relation to their U.S. competitors, we can evaluate it approximately by comparing the evolution of relative labour costs using the following formula:

$$\left(\Delta HW_{CAN} - \Delta HW_{US}\right) - \left(\Delta LP_{CAN} - \Delta LP_{US}\right) + \Delta e = \Delta ULC_{CAN_{US\$}} - \Delta ULC_{US}$$

where HW is the hourly wage, LP is labour productivity, *e* is the exchange rate and ULC is the unit labour cost.

The change in the relative cost of labour expressed in a common currency (in this case, the U.S. dollar) introduces three components that can have an impact on competitiveness between two countries:

(1) the relative evolution of the hourly wage;

(2) the difference in productivity gains between the two countries;

(3) the exchange rate, (which by giving the value of the Canadian dollar in U.S. dollars, makes it possible to make cost comparisons in a common currency).

Table 5.6 Canada-U.S. Comparison of the Evolution of the ULC in Manufacturing, 1992-2000*

	Canada	United States**	Gain or Loss for Canada
		Variation over the period (%)	
Labour Productivity	16.5	44.7	28.2 (loss)
Hourly Compensation	17.0	30.1	13.1 (gain)
ULC in CAN$	0.6	–	–
ULC in US$	-18.3	-10.1	8.2 (gain)
Depreciation of Canadian Dollar	18.6	–	18.6 (gain)

* In this particular instance, the data incorporate the treatment of software expenditures in the manufacturing sector as investment in the measurement of output. In incorporating this change, Canada is conforming to U.S. practice. This improves the comparability of the productivity measure and the ULC with that published by the U.S. Bureau of Labor Statistics.

** Source: U.S. Bureau of Labor Statistics.

An improvement of Canada's competitive position in relation to the United States may therefore come from:

– a reduction in domestic ULCs (as a result of a more rapid growth in productivity or a slower increase in wages);

– a rise in labour costs in the United States;

– a depreciation of the Canadian dollar in relation to the U.S. dollar.

Considering that in 2000, the U.S. market was the destination of 85.1% of Canadian merchandise exports, it is useful to compare the competitive position of the two countries' manufacturing sectors. Data on unit labour costs in the manufacturing sector are more suitable for evaluating the competitiveness of tradable goods produced in Canada, since services are not traded internationally to the same extent.

Table 5.6 compares evolution of unit labour costs in Canada and the United States between 1992 and 2000. As the table shows, there was an improvement in the unit labour costs of Canadian manufacturing industries in relation to their U.S. counterparts.

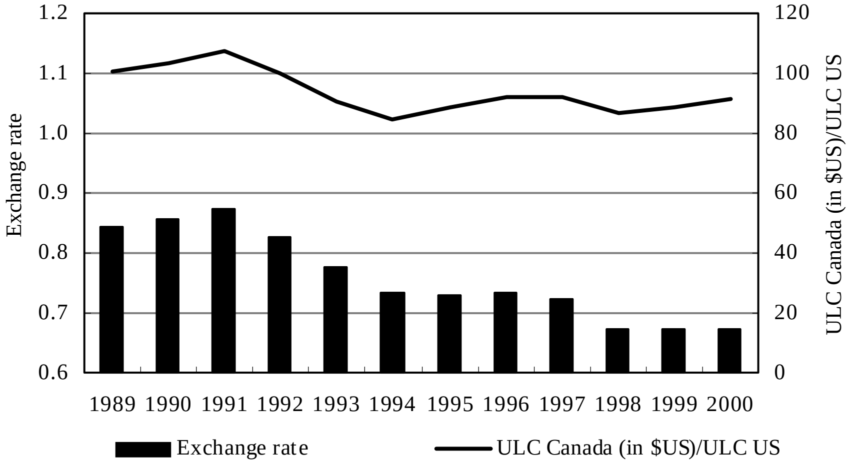
The ULC for the Canadian manufacturing sector, as expressed in U.S. dollars, declined 18.3% between 1992 and 2000. The American ULCs, for their part, declined 10.1% during the same period. Thus, Canada enjoyed an improvement in its relative unit labour costs in the manufacturing sector.

Despite this improvement in competitiveness, Canadian manufacturers have not done as well with respect to productivity as have their competitors in the United States over the same period. Between 1992 and 2000, the increase in productivity in the Canadian manufacturing sector (16.5%) was on average lower than that in the American manufacturing sector (44.7%).

At the same time, the hourly compensation paid to workers in the manufacturing sector increased less rapidly in Canada than in the United States. Over the period 1992-2000, it grew by only 17.0% in Canada, while it climbed 30.1% in the United States. As a result, the 28% gap in productivity growth in favour of American manufacturers was partially offset by lower wage growth (-13%) in Canada.

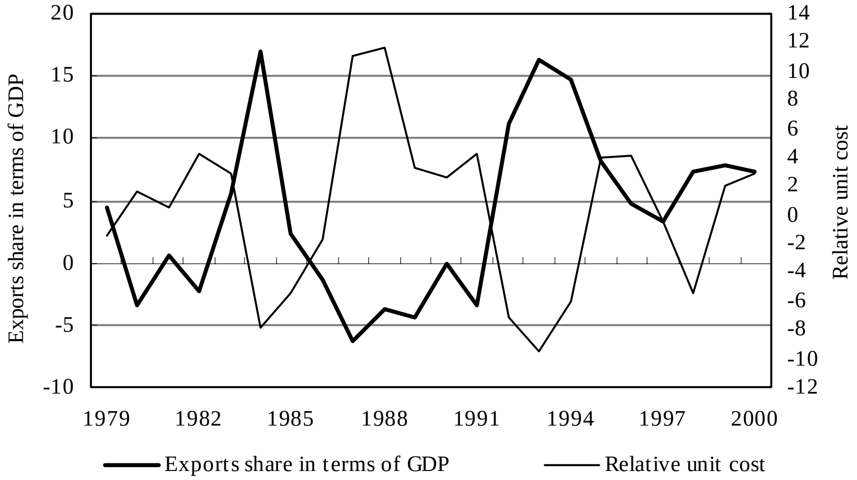
Between 1992 and 2000, the Canadian dollar lost value against the U.S. dollar, going from US$0.82 in 1992 to US$0.67 in 2000, a loss of 18.6% of its value (Figure 5.7).

Figure 5.7 Exchange Rate and Relative Labour Costs in the Manufacturing Industries, Canada- United-States: 1989-2000 (1992=100)



* The data used here also incorporate the treatment of software expenditures in the manufacturing sector as investment in the measurement of output. The U.S. data are from the U.S. Bureau of Labor Statistics.

Figure 5.8 Exports Share in Terms of GDP and Relative Unit Cost, 1979-2000 (percent change)



* The **relative unit cost** is defined as the difference between the growth rates of the unit labour cost in Canada and the United States, with these costs being expressed in U.S. dollars for purposes of comparison. A negative rate for the relative unit cost indicates an improvement in the competitiveness of the Canadian manufacturing sector.

Ultimately, this was what enabled Canadian manufacturers to maintain their competitiveness. In other words, the improvement in the performance of the Canadian manufacturing sector in the U.S. market was not due to higher productivity gains than our U.S. partners; rather it was due to slower wage growth (-13%) and the depreciation of the Canadian dollar in relation to its U.S. counterpart (-19%).

5.6.1 Exports Are Sensitive to Changes in Unit Costs

Since it has a limited domestic market, Canada depends greatly on international trade. Most of our merchandise trade, in both imports and exports, is with the United States. In 2000, 85.1% of all Canadian merchandise exports went to the U.S. market.

The evolution of ULCs is one of the factors that determines the competitiveness of Canadian-manufactured goods on the international market. A stabilization or even a decrease in labour costs enables businesses to keep their prices competitive internationally. This favours an increase in exports.

The improvement of the cost competitiveness of Canadian manufacturing industries has probably helped bolster exports since 1992 (Figure 5.8). Exports of merchandise to the U.S. market increased substantially during this period. More specifically, the exports of Canadian manufacturing businesses grew by an average of 14.3% per year during the period 1992-2000. The gradual adoption of the North American Free Trade Agreement and the robust and uninterrupted growth of the U.S. economy in the 1990's have also contributed to the surge in Canadian exports to the United States. This long-term trend was encouraged by a substantial growth in the U.S. economy. But deviations around the trend were closely related to changes in unit labour costs, as Figure 5.8 shows.

5.7 The Relationship Between Relative Unit Cost and Export Growth, by Manufacturing Industry Group

In order to better understand the relationship between unit labour costs and export success, we examine the relationship between the relative unit cost in the manufacturing sector of Canada and the United States and exports as a proportion of the GDP on an industry-by-industry basis.

The relative unit cost and Canadian exports are examined for 19 industry groups in the manufacturing sector in Canada and the United States. For both countries, the manufacturing sector includes the forest industry, which in Canada's case has included the wood industry for purposes of comparison.

Each industry's share of Canadian manufacturing exports is presented in Table 5.7 for 1981 and 1997. Transportation equipment industries account for the largest proportion (approximately one-third in 1997) of all manufacturing exports. In 1997, electrical and electronic products (9.4%), followed by paper and allied products (9.2%) and primary metal (8.4%), also accounted for a major proportion of Canadian exports of manufactured products.

Between 1981 and 1997, transportation equipment and electrical and electronic products increased their share of exports (by 22% and 75% respectively). On the other hand, during the same period, exports of the paper and allied products and primary metal industries declined in importance; their proportional shares decreased by 42.5% and 35.0% respectively. The shares of other groups of manufacturers ranged between 0.1% for tobacco industries and 7.6% for wood industries.

Table 5.7 Industry Share of Total Manufacturing Exports,* 1981 and 1997

Industry	1981	1997
	%	
Transportation Equipment	26.8	32.8
Electrical and Electronic Products	5.4	9.4
Paper and Allied Products	16.0	9.2
Primary Metal	12.9	8.4
Wood	6.6	7.6
Chemical and Chemical Products	6.6	6.1
Food and Beverage	6.8	5.1
Machinery Industries (except electrical machinery)	5.9	4.9
Fabricated Metal Products	2.2	2.8
Refined Petroleum and Coal Products	4.6	2.7
Plastic and Rubber Products	1.3	2.6
Other Manufacturing	1.6	2.5
Furniture and Fixture	0.5	1.9
Clothing and Textile Products	0.6	1.2
Non-metallic Mineral Products	1.0	1.1
Primary Textile	0.5	0.8
Printing, Publishing and Allied	0.4	0.6
Leather and Allied Products	0.2	0.1
Tobacco	0.2	0.1

* Data source: International Trade Division of Statistics Canada.

In general, when we compare relative ULCs with exports by industry, we observe an inverse relationship between these two variables (see figures in Appendix 5.B). As the Canada/U.S. relative unit cost decreases, exports rise. Of course, there are exceptions for some industries, but on the whole, this inverse relationship appears to be confirmed.

As seen above, changes in the relative unit cost result directly from three factors: the increase in relative hourly compensation (the difference in the growth of compensation between Canada and the United States), the relative growth of labour productivity (the difference in labour productivity growth between Canada and the United States), and the exchange rate for the Canadian dollar in relation to its U.S. counterpart (which allows comparisons in the same currency). All things being equal, a decrease in the relative unit cost in a given industry will result in a decrease in the relative prices of the goods and services that it produces, which should in turn lead to an increase in the demand for these products on external markets.

In order to better identify the relationship between relative ULCs and export growth, the coefficient of correlation between these two variables was calculated for the 19 industry groups. For 16 of them, negative coefficients of correlation were obtained (see Table 5.8). The three exceptions were manufacturers of metal products, refined petroleum and coal products and primary metals, which posted coefficients of correlation of 0.0, 0.33 and 0.42 respectively.

For a number of industries, the coefficient of correlation is negative and highly significant. This indicates that there is a negative relationship between relative unit labour costs and exports, but the strength of this relationship differs from one industry to another. Lumber (-0.73), clothing and textile products (-0.65), plastic and rubber products (-0.65), paper and allied products (-0.63), printing and publishing (-0.61) and non-metallic mineral products (-0.60) are among the Canadian industries most sensitive to changes in relative ULCs.

Table 5.8 Correlation between Export Growth and Relative Unit Cost, by Manufacturing Industry,* 1982-1997

Industry	Coefficient of Correlation
Wood	-0.73 ***
Clothing and Textile Products	-0.65 ***
Plastic and Rubber Products	-0.65 ***
Paper and Allied Products	-0.63 ***
Printing, Publishing and Allied	-0.61 ***
Non-metallic Mineral Products	-0.60 ***
Machinery Industries (except electrical machinery)	-0.52 ***
Food and Beverage	-0.44 ***
Primary Textile	-0.42 ***
Furniture and Fixture	-0.40
Other Manufacturing**	-0.38
Leather and Allied Products	-0.38
Chemical and Chemical Products	-0.33
Tobacco	-0.24
Transportation Equipment	-0.21
Electrical and Electronic Products**	-0.15
Fabricated Metal Products	-0.02
Refined Petroleum and Coal Products	0.33
Primary Metal	0.42

* Source of U.S. data: U.S. Bureau of Economic Analysis and U.S. Bureau of Labor Statistics.

** For the electrical and electronic products industries and other manufacturing industries, the coefficient of correlation between the variables is calculated for the period 1988-1997.

*** Significantly different from zero.

The coefficients of correlation of the other industry groups vary between -0.15 for electrical and electronic products industries and -0.52 for machinery industry (except electrical machinery). Transportation equipment industries, which account for a third of exports of all manufacturing industries combined, are less sensitive to changes in the relative ULC. The same is true for electrical and electronic products and metal products. Lastly, the positive relationship observed between the relative ULC and changes in exports for refined petroleum products and less processed metals seems to indicate that factors other than labour cost differences are at play for these industries.

5.8 Summary and Conclusion

In this chapter, we have reviewed the basic concepts needed to understand the notion of unit labour cost. The ULC indicator was compared with a broader measure, the UVC, which represents all variable costs of inputs used in production. A very strong correlation between the two cost measures was observed during the period 1961-1997, not only in the business sector but also in manufacturing. The ULC provides a timely indicator of short-term pressures on variable costs.

We then described the usefulness of the ULC and the main factors that affect its evolution. By making comparisons with the ULC in the United States, we examined the role of the ULC as an indicator of competitiveness and as a factor behind the observed upward trends in Canadian exports over the 1992-2000 period.

By measuring the cost competitiveness of the manufacturing sector in terms of relative unit labour costs, we outlined the advantage that has developed for Canadian manufacturers. The gap in unit costs between the two countries, expressed in U.S. dollars, has developed in Canada's favour since1992. However, this competitive advantage in relation to the United States is not due to productivity gains; these lag behind those recorded in the United States; instead, it is due to the weakness of the Canadian dollar and lower wage rates.

We also examined in greater detail the link between the evolution of the relative unit cost and export growth for 19 comparable industry groups. Coefficients of correlation between the relative unit cost and export growth were negative for 90% of the industry groups. There is an inverse relationship between changes in relative costs and the evolution of exports, but the scope of this relationship differs from one industry to another.

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Appendix 5.A—A Brief Overview of Concepts of Costs in a Business

Total Cost of Production in Businesses

The concept of cost is central to a business's economic accounting. In general, cost refers to the expense that the business incurs in its production. It is an important concept, since knowledge thereof enables the business to set the selling price of the goods and services that it produces in order to cover its costs. In accounting terms, it is the difference between the receipt from sales and the total cost (all expenses incurred) which, among other things, makes it possible to provide compensation for consultants' services, a fund for new production equipment and dividends for the capital used.

The cost of production, which is made up of all the costs generated in producing a product intended for sale, generally corresponds to the total cost of all the activities of the business. Thus, the cost of production is defined as the sum of expenditures relating to the manufacture and sale of the good or service produced. Depending on the analytical viewpoint, a distinction is sometimes made between the cost of production, including the cost of acquisition of raw materials and intermediate goods as well as the manufacturing cost (wage costs and miscellaneous expenses) and the distribution cost, which consists of the expenses associated with selling (distribution network, advertising, etc.).

Fixed Costs, Variable Costs and Unit Variable Cost of Production

Generally, two components of the total cost of production are distinguished. The fixed cost (FC), which is a basic cost, is independent of the short-term level of production. In general, it corresponds to the costs of maintaining equipment (whether it is being operated or not), its financial depreciation, various types of insurance, the salaries of management, administration, office and sales staff and various overhead costs. In some industries, such as the motor vehicle and aircraft industries, fixed costs are very significant because of the activities of these industries that require sizable prior expenditures on research and capital investment.

On the other hand, the other component, the variable cost (VC), as its name indicates, varies in the short run according to the volume of activity. Labour, raw materials, energy and the services used in the production process are examples of expenses included in variable costs. Some components of the variable cost vary proportionally to the quantity produced, such as raw materials and intermediate goods; others increase at a different rate, such as the labour cost when there is overtime, since the latter is generally paid at a higher rate.

The total cost of production (TC) may be written as follows: TC = FC + VC

If we know the total cost of production and the units produced (Q), we can calculate the *unit cost of production, as follows*:

$$UCP = \frac{TC}{Q} \quad ;$$

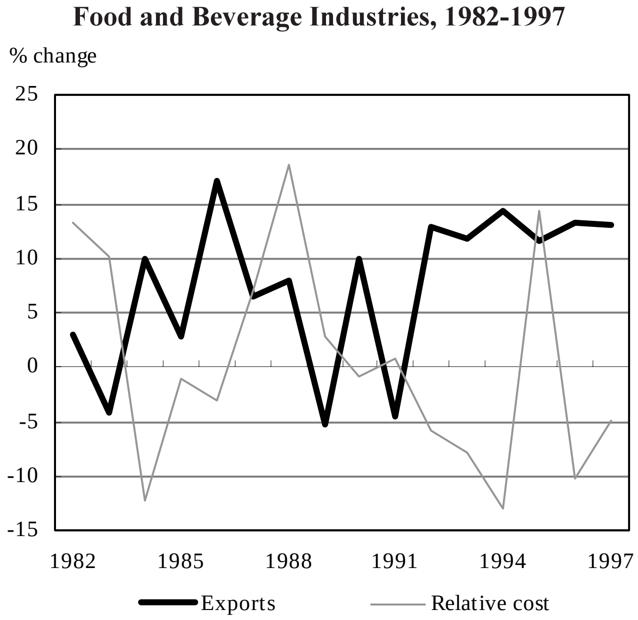
The *unit variable cost* (or *average variable cost*) may also be calculated by taking the ratio between the variable cost and the quantities produced, as follows:

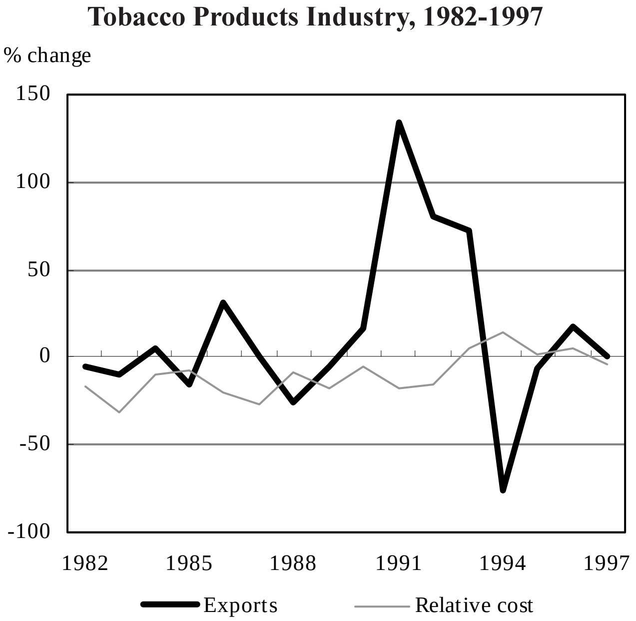
$$UVC = \frac{VC}{Q} \quad .$$

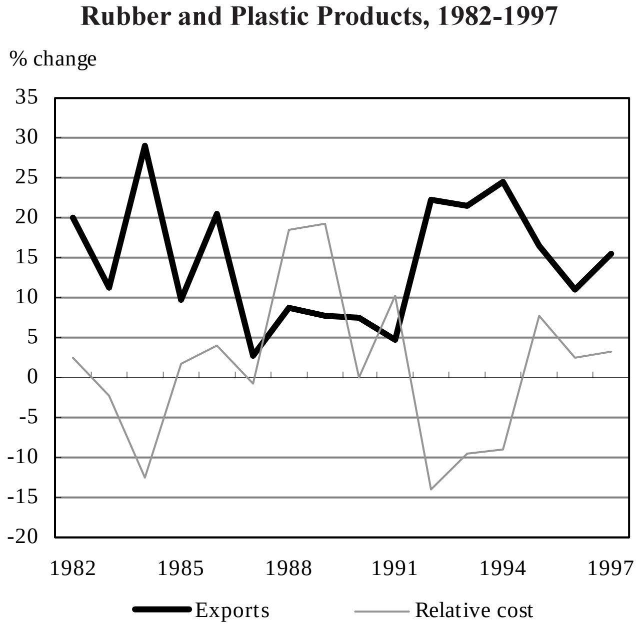
Labour Cost

Here, the concept of labour cost refers to all expenses borne by employers for the use of labour. Wages are paid by businesses in the form of gross compensation (gross wages). Compensation for overtime is also taken into account. However, the wage cost or the total compensation of labour does not consist solely of wages but also includes fringe benefits. These are divided into three main components: time compensated but not worked, private or public insurance, and private or public pension funds. The costs of fringe benefits borne by Canadian businesses can represent up to a third of the average compensation of employees. Thus, the labour cost is made up of gross wages plus fringe benefits. For the purposes of productivity measures, total labour costs should include not only compensation of the labour of employees, but also compensation of the labour of self-employed workers.

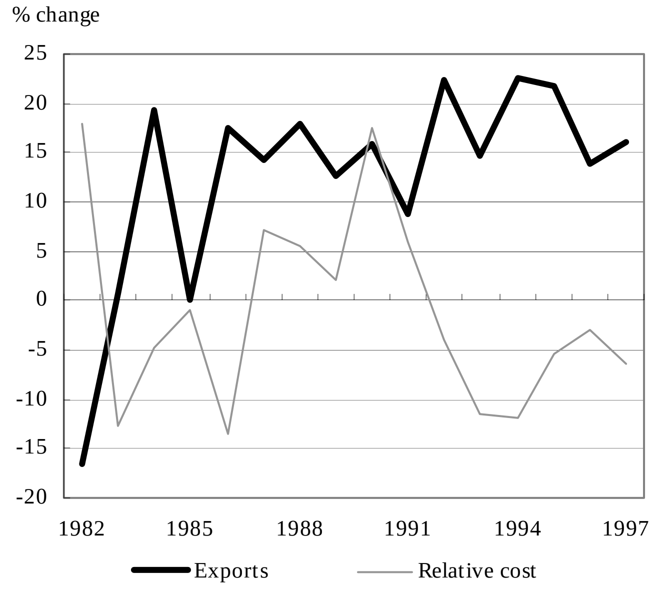
Appendix 5.B—Exports and Relative Unit Cost by Manufacturing industry 1982-1997



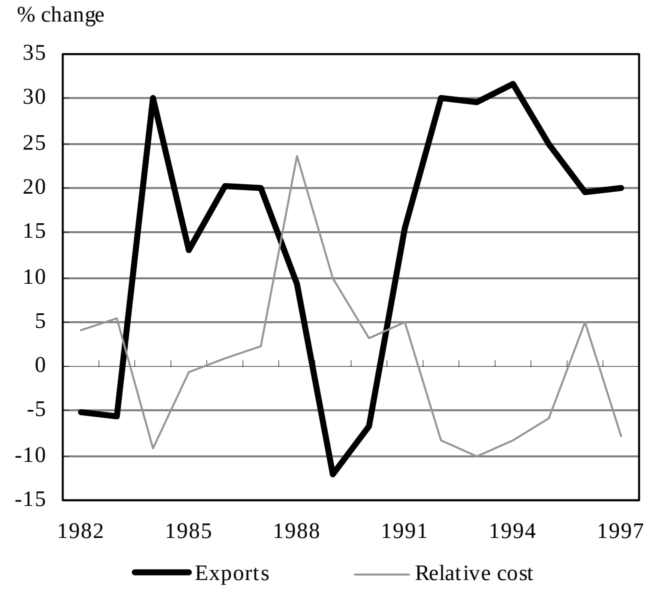




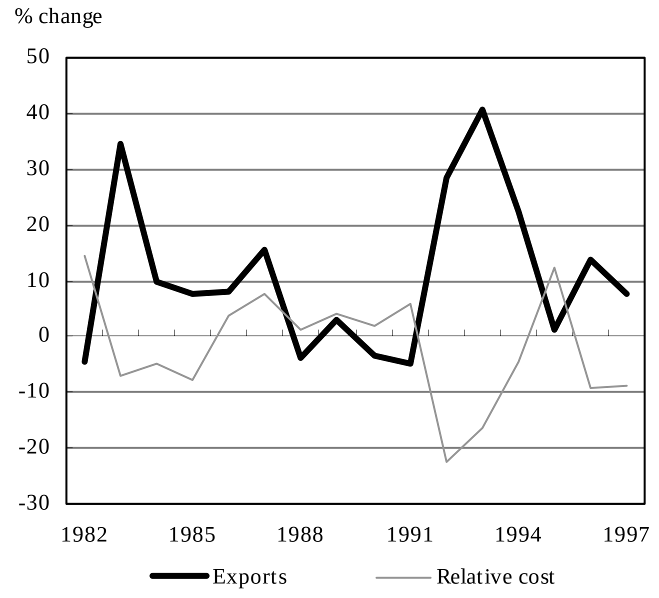
Primary Textile Industries, 1982-1997



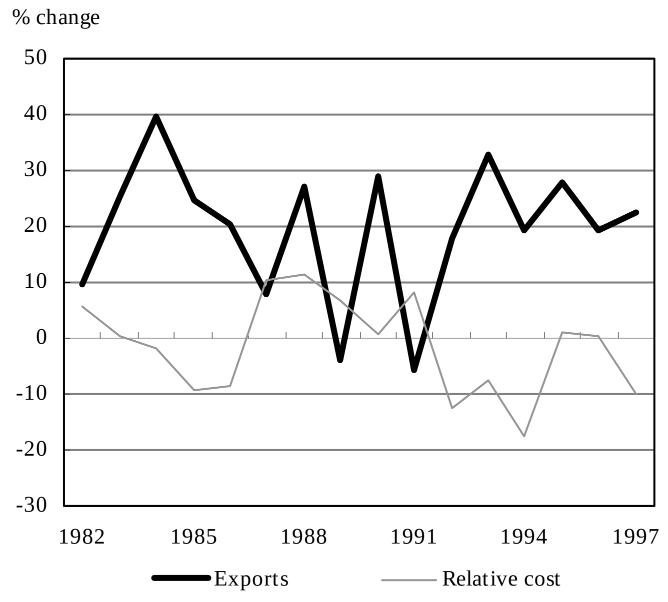
Clothing and Other Textile Products, 1982-1997



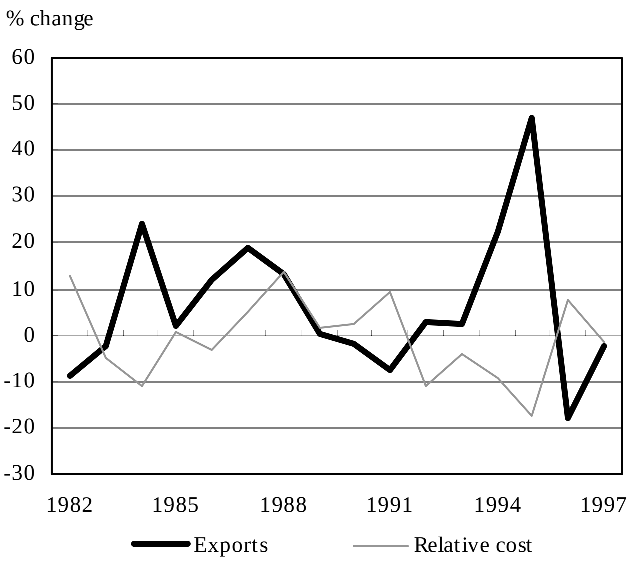
Wood Industries, 1982-1997



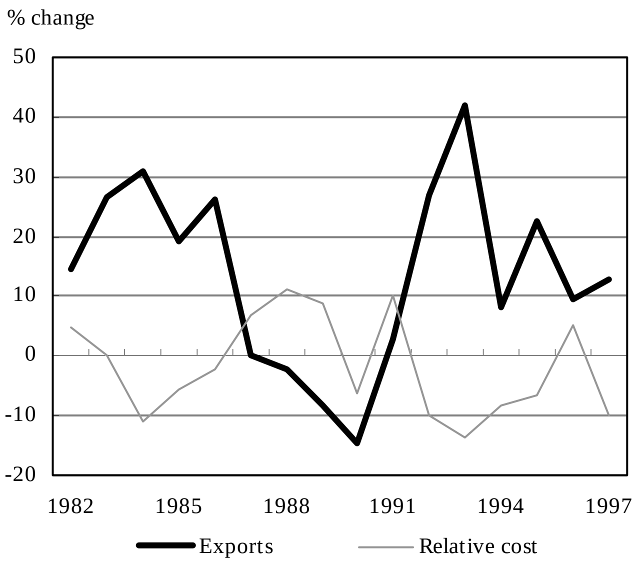
Furniture and Fixture Industries, 1982-1997



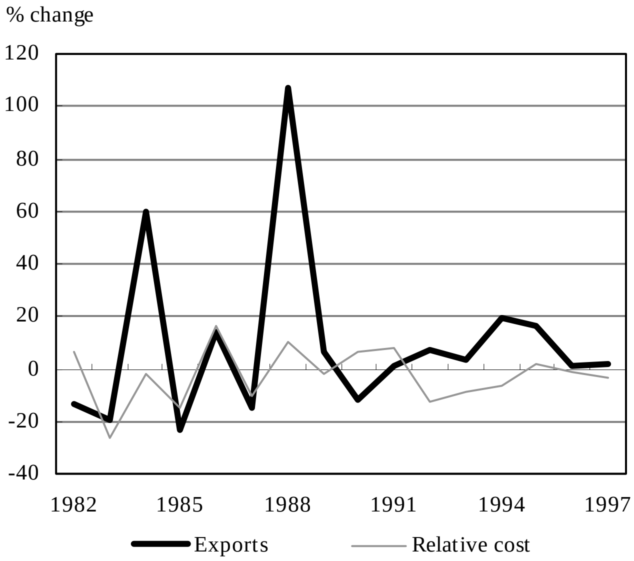
Paper and Allied Products Industries, 1982-1997



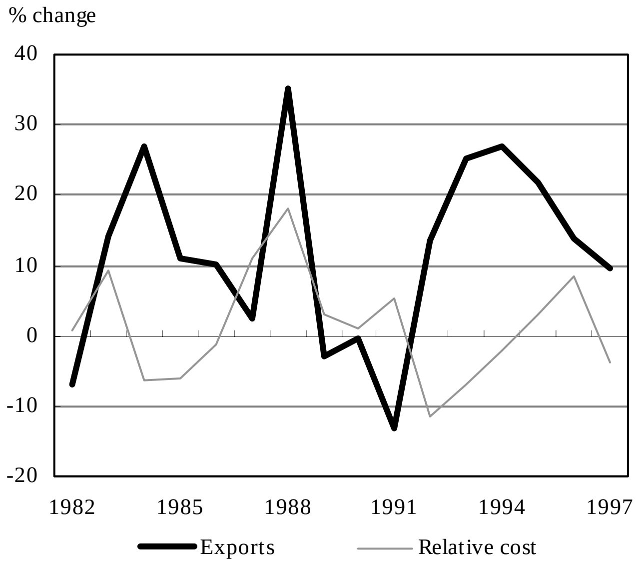
Printing, Publishing and Allied Industries, 1982-1997



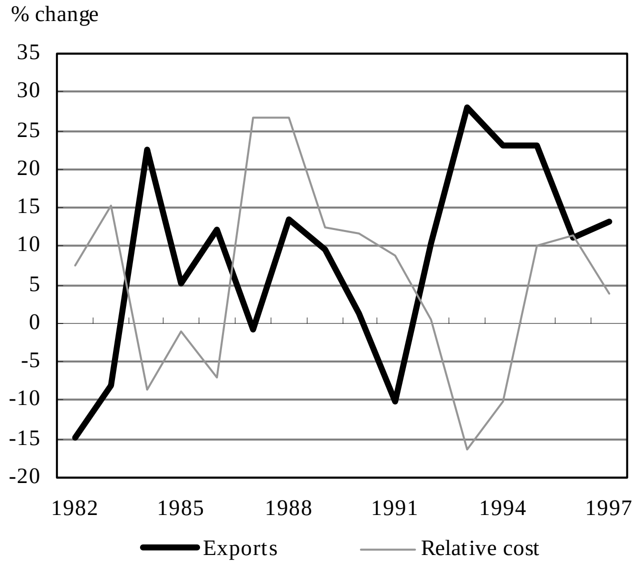
Primary Metal Industries, 1982-1997



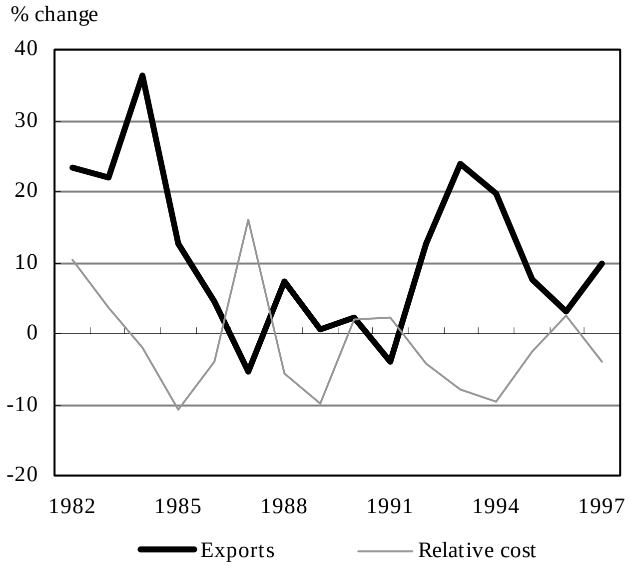
Fabricated Metal Products Industries, 1982-1997



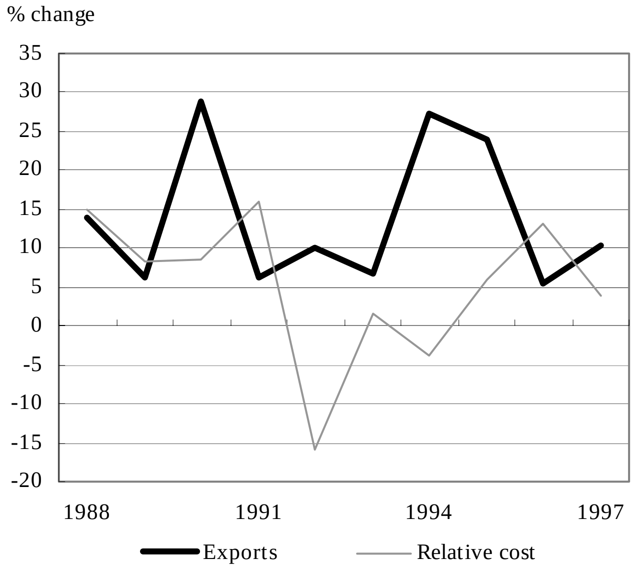
Machinery Industries (except electrical machinery), 1982-1997



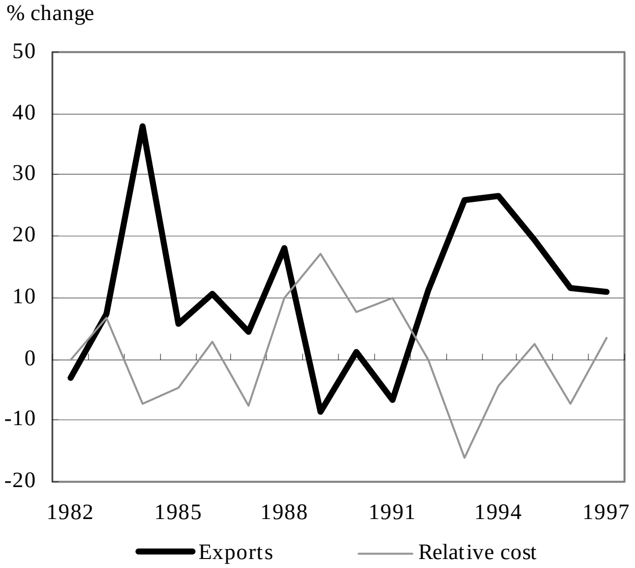
Transportation Equipment Industries, 1982-1997



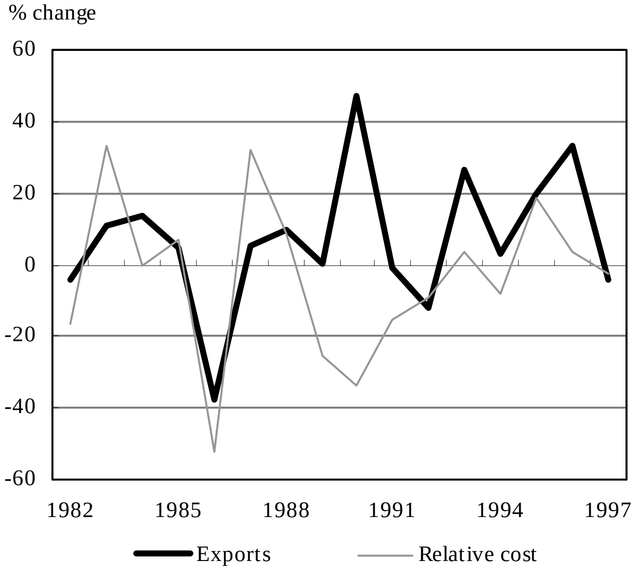
Electrical and Electronic Products Industries, 1988-1997



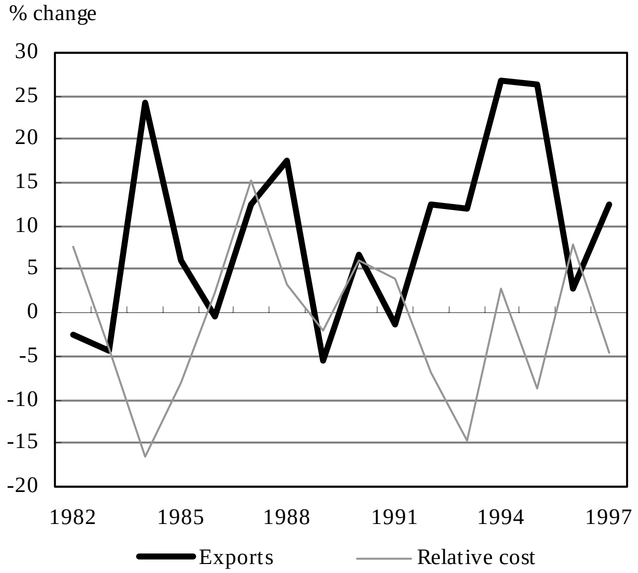
Non-metallic Mineral Products Industries, 1982-1997



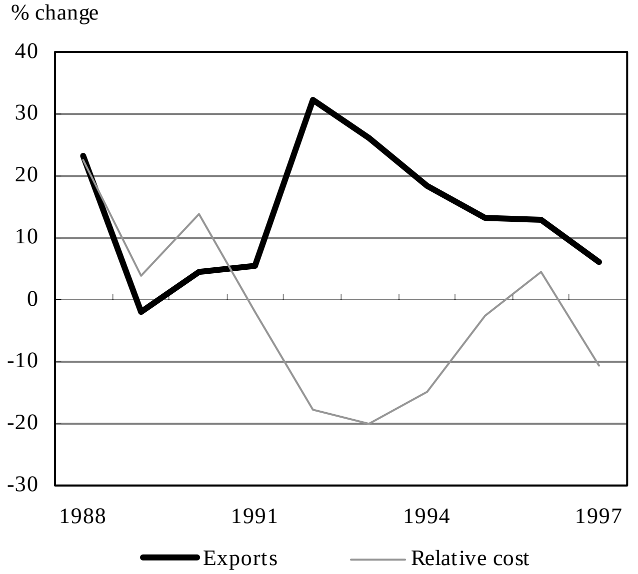
Refined Petroleum and Coal Products Industries, 1982-1997



Chemical and Chemical Products Industries, 1982-1997



Other Manufacturing Industries, 1988-1997



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Data Appendix—Productivity Series and Related Measures

Methodological note

These tables present data for the business sector and its 16 major sectors based on the 1980 standard industrial classification. The business sector includes all of gross domestic product except the output of general government, non-profit institutions and the rental value of owner-occupied real estate.

For the business sector productivity measures, output is measured as real GDP—deliveries in constant chained dollars of final goods and services by the business sector to domestic households, investment, government and non-profit institutions, and net exports to other countries. Business sector GDP series reported in the 2001 edition of this publication were based on an aggregation of real value added across industries. At the industry level, output is defined in terms of real value added. Real value added series reflect both the real contribution of capital and labour in converting intermediate inputs into finished products by industry. The estimates of output reflect the capitalization of software expenditures.

Capital input services measure the services derived from the stock of physical assets and software. The assets included are fixed business equipment, structures, inventories, and land. The 2001 edition of this publication used capital stock.

Labour input services are obtained by aggregation of the hours worked by all persons, classified by education and work experience with weights determined by their shares of labour compensation. The 2001 edition of this publication used the sum of hours at work.

Capital-labour ratio is the ratio of capital services to hours worked.

Multifactor productivity is measured as the ratio of output per unit of combined inputs (capital services and labour services). Labour productivity is measured as output per hour worked.

Capital productivity is measured as output per unit of capital services.

Combined inputs. Labour input combined with capital input, using labour's and capital's share of costs as weights to form a Fisher chained index.

Total compensation per hour is measured as the ratio of labour compensation for all jobs to the number of hours at work.

Unit labour cost is the ratio of labour compensation per unit of real GDP.

Table 1a. Productivity and Related Measures, 1981-2000, Index 1997=100

	Business Sector										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	66.1	80.7	98.7	81.5	70.3	61.2	66.7	76.3	108.2	52.1	63.6
1982	62.8	76.7	95.2	81.6	67.5	62.8	65.8	82.1	100.2	57.3	70.0
1983	64.8	76.7	96.9	84.1	68.1	64.1	66.6	83.8	101.1	59.8	70.8
1984	69.7	79.1	101.4	87.9	70.6	65.6	68.7	83.1	106.6	62.9	71.3
1985	73.3	82.4	102.2	88.6	73.9	68.0	71.6	82.6	108.1	65.8	74.0
1986	75.1	85.2	100.8	88.0	77.0	70.4	74.5	82.9	106.9	68.0	77.1
1987	79.0	88.7	101.0	88.8	80.7	73.7	78.0	83.3	107.4	71.6	80.3
1988	82.9	92.6	100.7	89.4	85.2	77.5	82.2	83.9	107.3	76.0	84.8
1989	84.8	94.7	99.1	89.4	87.8	81.5	85.4	86.3	104.2	80.0	89.4
1990	83.7	94.2	96.6	88.6	87.8	84.0	86.4	89.4	99.6	83.5	94.0
1991	79.9	90.2	93.4	88.5	85.2	85.7	85.4	95.1	93.1	88.0	99.3
1992	80.3	88.5	93.9	90.5	84.6	86.7	85.3	97.9	92.4	90.9	100.2
1993	82.7	89.8	94.6	91.8	87.1	87.5	87.2	97.3	94.4	91.5	99.4
1994	88.6	92.9	98.1	95.3	90.8	89.7	90.3	96.5	98.8	91.6	95.9
1995	92.1	94.4	99.4	97.6	92.9	92.3	92.7	97.8	99.8	94.0	96.3
1996	94.4	96.8	98.7	97.4	95.8	95.2	95.6	98.3	99.1	95.5	98.0
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	104.5	102.8	101.0	101.7	102.7	104.7	103.5	102.0	99.8	103.9	102.2
1999p	111.5	106.8	103.8	104.6	106.5	109.4	107.6	102.6	102.0	105.0	100.5
2000p	117.5	110.0	105.1	107.0	110.8	113.9	112.0	103.7	103.3	111.4	104.3

p The symbol p means that the series are preliminary.

Table 1b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Business Sector										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-4.9	-5.1	-3.5	0.1	-3.9	2.5	-1.4	7.6	-7.4	10.1	9.9
1983	3.1	0.0	1.8	3.1	0.8	2.2	1.3	2.1	0.9	4.3	1.2
1984	7.7	3.2	4.6	4.5	3.7	2.2	3.1	-0.9	5.4	5.1	0.7
1985	5.1	4.3	0.8	0.8	4.7	3.7	4.3	-0.6	1.4	4.6	3.8
1986	2.5	3.3	-1.4	-0.8	4.2	3.6	4.0	0.3	-1.1	3.4	4.2
1987	5.1	4.1	0.3	1.0	4.9	4.7	4.8	0.6	0.4	5.2	4.2
1988	5.0	4.4	-0.3	0.6	5.5	5.1	5.3	0.7	-0.1	6.2	5.6
1989	2.3	2.3	-1.6	-0.1	3.1	5.1	3.9	2.8	-2.8	5.3	5.4
1990	-1.4	-0.6	-2.5	-0.8	0.0	3.1	1.2	3.7	-4.5	4.3	5.2
1991	-4.4	-4.2	-3.3	-0.2	-3.0	2.1	-1.2	6.3	-6.5	5.4	5.6
1992	0.4	-1.8	0.5	2.3	-0.7	1.1	-0.1	3.0	-0.7	3.2	0.9
1993	3.0	1.5	0.8	1.5	3.0	0.9	2.2	-0.6	2.1	0.7	-0.8
1994	7.2	3.4	3.6	3.8	4.1	2.5	3.6	-0.9	4.7	0.0	-3.5
1995	3.9	1.6	1.4	2.3	2.3	2.9	2.6	1.3	1.0	2.7	0.4
1996	2.4	2.6	-0.7	-0.1	3.2	3.1	3.1	0.5	-0.7	1.6	1.7
1997	6.0	3.3	1.4	2.6	4.3	5.1	4.6	1.8	0.9	4.7	2.1
1998[p]	4.5	2.8	1.0	1.7	2.7	4.7	3.5	2.0	-0.2	3.9	2.2
1999[p]	6.7	3.9	2.7	2.8	3.6	4.5	4.0	0.6	2.2	1.0	-1.7
2000[p]	5.3	3.0	1.3	2.3	4.1	4.1	4.1	1.1	1.3	6.2	3.8

[p] The symbol p means that the series are preliminary.

Table 2a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Agriculture and Related Services										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	70.2	108.1	65.9	65.5	90.4	129.2	107.6	120.4	55.4	49.4	76.0
1982	72.7	108.5	68.0	67.5	91.9	128.2	107.9	118.9	57.8	52.6	78.5
1983	69.5	106.1	66.0	66.0	90.2	126.4	106.2	119.9	56.0	56.2	85.8
1984	68.2	106.3	64.9	64.7	91.3	124.9	106.1	118.2	55.7	57.3	89.3
1985	71.2	110.5	67.1	64.9	95.9	121.8	107.2	110.6	59.5	59.9	93.0
1986	81.4	108.8	78.0	75.3	94.5	118.9	105.1	109.7	69.5	62.4	83.4
1987	76.8	106.8	75.1	72.4	93.7	115.3	103.0	108.4	67.6	65.8	91.5
1988	70.0	104.3	69.8	67.7	93.5	111.3	101.3	107.2	64.0	70.9	105.5
1989	81.3	103.2	82.1	79.3	93.8	107.1	99.7	104.2	76.7	75.3	95.6
1990	94.9	102.6	98.0	93.0	92.8	102.5	97.0	100.4	92.8	78.3	84.7
1991	96.0	95.9	103.3	100.2	87.9	99.5	93.0	104.0	96.7	81.5	81.4
1992	88.3	98.0	93.8	90.0	91.6	96.9	94.0	99.0	91.4	83.5	92.7
1993	95.0	99.9	99.0	95.0	95.3	96.6	95.9	96.7	98.6	85.9	90.4
1994	96.4	99.8	99.2	96.5	97.6	96.4	97.2	96.7	100.3	91.5	94.8
1995	99.3	98.4	102.7	100.8	96.8	96.3	96.7	97.9	103.4	92.4	91.6
1996	104.9	100.6	106.3	104.2	100.5	96.5	98.7	96.0	109.0	96.2	92.3
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	106.2	96.3	105.0	110.0	98.8	104.7	101.2	108.4	101.6	112.0	101.5
1999[p]	115.6	90.7	115.9	125.9	93.7	107.7	99.6	117.8	107.5	108.8	85.4
2000[p]	113.0	87.4	119.3	127.9	83.2	110.9	94.5	125.6	102.0	106.8	82.6

[p] The symbol p means that the series are preliminary.

Table 2b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Agricultural and Related Services										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	3.5	0.4	3.2	3.0	1.7	-0.8	0.2	-1.3	4.3	6.3	3.3
1983	-4.4	-2.2	-2.9	-2.2	-1.8	-1.4	-1.6	0.9	-3.1	6.8	9.3
1984	-1.7	0.2	-1.7	-1.9	1.2	-1.2	-0.1	-1.4	-0.5	2.1	4.1
1985	4.3	3.9	3.3	0.3	5.0	-2.5	1.0	-6.4	6.7	4.5	4.1
1986	14.4	-1.6	16.3	16.0	-1.4	-2.4	-2.0	-0.8	16.8	4.3	-10.3
1987	-5.6	-1.8	-3.7	-3.8	-0.8	-3.0	-1.9	-1.1	-2.6	5.4	9.6
1988	-8.9	-2.3	-7.1	-6.5	-0.2	-3.5	-1.7	-1.2	-5.4	7.7	15.4
1989	16.1	-1.0	17.7	17.1	0.3	-3.8	-1.6	-2.7	19.8	6.2	-9.4
1990	16.7	-0.6	19.3	17.3	-1.1	-4.3	-2.6	-3.7	21.0	4.1	-11.4
1991	1.2	-6.5	5.4	7.8	-5.3	-3.0	-4.2	3.5	4.2	4.1	-3.9
1992	-8.1	2.2	-9.2	-10.3	4.3	-2.6	1.1	-4.7	-5.5	2.5	14.0
1993	7.6	2.0	5.5	5.6	4.0	-0.4	2.0	-2.3	7.9	2.8	-2.5
1994	1.5	-0.1	0.2	1.6	2.4	-0.2	1.3	-0.1	1.7	6.5	4.8
1995	3.0	-1.4	3.5	4.4	-0.8	-0.1	-0.5	1.3	3.1	1.0	-3.4
1996	5.7	2.2	3.5	3.4	3.8	0.3	2.1	-2.0	5.4	4.1	0.7
1997	-4.7	-0.6	-6.0	-4.1	-0.5	3.6	1.3	4.2	-8.2	4.0	8.4
1998p	6.2	-3.7	5.0	10.0	-1.2	4.7	1.2	8.4	1.6	12.0	1.5
1999p	8.8	-5.7	10.4	14.5	-5.1	2.9	-1.6	8.7	5.8	-2.9	-15.8
2000p	-2.2	-3.7	2.9	1.5	-11.2	2.9	-5.1	6.6	-5.1	-1.8	-3.3

p The symbol p means that the series are preliminary.

Table 3a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Fishing and Trapping										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	117.5	90.0	x	167.2	80.6	127.8	112.7	186.6	93.9	33.8	25.9
1982	126.3	90.9	x	178.1	82.3	119.8	108.1	173.1	106.8	36.1	26.0
1983	122.0	94.1	x	165.7	85.6	110.0	102.8	152.7	112.0	36.1	27.9
1984	109.7	98.0	x	142.2	89.4	99.8	97.3	132.5	111.0	38.0	33.9
1985	128.6	95.9	x	169.7	88.1	94.3	93.1	127.9	136.3	53.1	39.6
1986	133.0	105.5	x	158.6	97.6	92.6	95.3	112.8	143.4	58.0	46.0
1987	114.2	111.0	x	127.9	103.1	93.4	97.6	108.0	121.8	63.6	61.8
1988	128.4	126.1	x	126.3	118.3	94.3	103.1	94.3	135.8	68.5	67.3
1989	140.9	137.6	x	127.2	129.3	99.7	110.5	91.1	141.3	70.6	68.9
1990	159.5	152.0	x	130.6	143.3	103.1	118.3	84.7	155.1	74.7	71.1
1991	139.6	197.9	x	74.8	188.6	103.4	140.8	59.3	135.3	70.3	99.7
1992	127.0	146.8	x	87.4	141.9	103.4	119.9	74.6	123.1	78.2	90.4
1993	131.5	129.1	x	101.1	126.5	103.4	113.1	83.7	127.4	85.8	84.2
1994	108.1	115.3	x	93.9	113.2	104.2	107.7	93.3	103.7	99.7	106.4
1995	89.9	95.8	x	94.0	95.0	103.3	99.1	108.2	87.2	133.4	142.2
1996	92.8	100.4	x	92.4	100.1	100.9	100.5	100.5	92.0	115.2	124.6
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	98.8	95.7	x	103.1	95.6	100.3	98.0	104.6	98.5	131.3	127.1
1999[p]	98.1	100.9	x	96.8	101.4	100.6	101.1	99.2	97.5	105.9	109.0
2000[p]	96.7	102.1	x	94.2	102.4	101.8	102.2	99.2	95.0	95.9	101.2

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 3b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Fishing and Trapping										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	7.5	1.0	x	6.5	2.1	-6.2	-4.1	-7.2	13.7	7.0	0.5
1983	-3.4	3.6	x	-7.0	4.0	-8.2	-4.9	-11.8	4.8	0.0	7.2
1984	-10.1	4.1	x	-14.2	4.4	-9.2	-5.3	-13.3	-0.9	5.1	21.7
1985	17.2	-2.1	x	19.3	-1.5	-5.6	-4.3	-3.5	22.8	39.8	16.7
1986	3.4	10.0	x	-6.5	10.8	-1.8	2.3	-11.8	5.2	9.2	16.1
1987	-14.1	5.2	x	-19.4	5.7	0.9	2.4	-4.3	-15.0	9.7	34.4
1988	12.4	13.6	x	-1.2	14.7	0.9	5.6	-12.7	11.4	7.7	8.9
1989	9.8	9.1	x	0.7	9.3	5.7	7.2	-3.4	4.1	3.0	2.4
1990	13.2	10.5	x	2.7	10.8	3.5	7.1	-7.0	9.8	5.8	3.2
1991	-12.5	30.2	x	-42.7	31.6	0.2	19.0	-30.0	-12.8	-5.9	40.1
1992	-9.0	-25.8	x	16.8	-24.7	0.0	-14.8	25.8	-9.0	11.3	-9.3
1993	3.5	-12.1	x	15.6	-10.9	0.0	-5.7	12.1	3.5	9.6	-6.9
1994	-17.8	-10.7	x	-7.1	-10.5	0.8	-4.8	11.5	-18.6	16.3	26.4
1995	-16.8	-16.9	x	0.1	-16.0	-0.9	-8.0	16.0	-15.9	33.8	33.7
1996	3.2	4.8	x	-1.6	5.3	-2.3	1.4	-7.1	5.5	-13.7	-12.3
1997	7.8	-0.4	x	8.2	-0.1	-0.9	-0.5	-0.5	8.7	-13.2	-19.8
1998[p]	-1.2	-4.3	x	3.1	-4.4	0.3	-2.0	4.6	-1.5	31.3	27.1
1999[p]	-0.7	5.5	x	-6.2	6.0	0.3	3.1	-5.1	-1.0	-19.3	-14.3
2000[p]	-1.4	1.2	x	-2.6	1.0	1.2	1.1	0.0	-2.6	-9.5	-7.1

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 4a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Logging and Forestry										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	86.5	106.4	x	81.2	96.9	131.2	103.6	129.9	66.9	49.8	61.2
1982	75.6	93.2	x	81.0	86.0	120.8	92.6	135.6	63.8	52.8	65.1
1983	95.5	97.0	x	98.9	90.3	112.2	94.6	120.4	85.0	55.4	56.3
1984	102.4	98.6	x	104.5	92.2	107.7	95.0	113.7	94.6	60.6	58.4
1985	100.0	96.4	x	104.4	90.5	103.8	92.9	112.0	95.8	61.1	58.9
1986	95.4	95.6	x	100.4	90.0	101.0	91.9	109.9	94.0	62.8	63.0
1987	114.7	104.8	x	111.1	99.1	100.0	98.3	98.2	114.0	64.8	59.2
1988	116.2	104.9	x	112.5	99.7	100.5	98.8	98.7	114.9	67.5	60.9
1989	112.3	105.4	x	108.2	100.5	100.0	99.1	97.7	111.6	70.6	66.2
1990	98.6	98.4	x	102.1	94.2	98.5	94.5	102.8	99.6	73.6	73.4
1991	86.1	99.2	x	88.3	95.0	91.3	93.4	94.4	94.3	73.2	84.3
1992	87.6	93.1	x	95.3	90.7	88.8	89.5	97.6	98.5	79.6	84.6
1993	93.4	96.3	x	98.3	94.8	90.8	92.9	96.5	102.7	82.7	85.3
1994	99.1	96.7	x	103.8	95.6	95.0	95.1	100.5	104.3	87.5	85.5
1995	103.2	109.8	x	94.2	108.9	96.3	103.6	88.3	107.2	91.8	97.6
1996	97.3	101.9	x	95.6	101.5	97.0	99.7	95.3	100.3	95.9	100.4
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	98.2	95.3	x	102.9	94.9	102.3	97.8	107.0	95.9	101.9	98.9
1999[p]	108.0	96.9	x	111.5	96.5	103.0	99.1	105.9	104.8	99.8	89.5
2000[p]	110.4	105.1	x	104.5	105.3	104.2	105.0	98.3	105.8	107.6	102.5

[p] The symbol p means that the series are preliminary.
[x] The symbol x means that the series has been suppressed for quality reasons.

Table 4b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Logging and Forestry										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-12.6	-12.4	x	-0.2	-11.3	-8.0	-10.6	4.4	-4.6	6.1	6.4
1983	26.2	4.1	x	22.2	5.0	-7.1	2.2	-11.2	33.3	5.0	-13.4
1984	7.2	1.6	x	5.6	2.1	-4.0	0.4	-5.6	11.2	9.4	3.7
1985	-2.3	-2.2	x	-0.1	-1.8	-3.7	-2.2	-1.4	1.3	0.8	0.9
1986	-4.6	-0.8	x	-3.8	-0.6	-2.7	-1.1	-1.9	-1.9	2.8	6.9
1987	20.3	9.6	x	10.7	10.1	-1.0	6.9	-10.6	21.3	3.1	-6.0
1988	1.3	0.1	x	1.3	0.6	0.6	0.6	0.5	0.8	4.3	3.0
1989	-3.4	0.5	x	-3.8	0.8	-0.6	0.3	-1.0	-2.8	4.5	8.6
1990	-12.2	-6.7	x	-5.6	-6.2	-1.5	-4.6	5.2	-10.8	4.3	10.9
1991	-12.7	0.8	x	-13.5	0.8	-7.4	-1.2	-8.2	-5.3	-0.5	14.9
1992	1.8	-6.1	x	7.8	-4.6	-2.7	-4.1	3.4	4.4	8.7	0.4
1993	6.6	3.4	x	3.2	4.6	2.3	3.8	-1.1	4.3	3.9	0.8
1994	6.1	0.4	x	5.7	0.8	4.6	2.3	4.2	1.5	5.8	0.2
1995	4.2	13.5	x	-9.3	14.0	1.4	9.0	-12.1	2.8	4.9	14.2
1996	-5.7	-7.2	x	1.5	-6.9	0.8	-3.8	7.9	-6.5	4.5	2.9
1997	2.7	-1.9	x	4.6	-1.4	3.0	0.3	5.0	-0.3	4.3	-0.4
1998[p]	-1.8	-4.7	x	2.9	-5.1	2.3	-2.2	7.0	-4.1	1.9	-1.1
1999[p]	10.0	1.6	x	8.3	1.7	0.6	1.3	-1.0	9.3	-2.1	-9.5
2000[p]	2.2	8.5	x	-6.3	9.1	1.2	6.0	-7.2	1.0	7.9	14.5

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 5a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Mining, Quarrying and Oil Well										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	64.9	100.7	x	65.6	88.5	67.3	71.6	68.1	97.5	47.7	74.0
1982	63.6	97.0	x	66.7	86.5	72.8	76.0	76.2	87.7	55.1	84.0
1983	68.0	93.2	x	73.9	84.2	76.4	78.7	83.0	89.3	59.3	81.2
1984	74.7	98.3	x	77.2	89.6	79.4	82.0	81.6	94.7	62.3	82.0
1985	79.2	102.0	x	78.8	93.8	83.2	86.0	82.5	95.8	65.1	83.9
1986	75.2	97.9	x	78.1	90.8	83.7	85.7	86.2	90.4	66.4	86.5
1987	78.6	94.1	x	84.6	87.6	83.5	84.8	89.5	94.6	66.5	79.7
1988	85.5	97.2	x	89.3	91.3	84.0	86.1	87.0	102.5	71.6	81.3
1989	79.8	96.7	x	83.7	91.6	83.1	85.5	86.5	96.7	74.6	90.4
1990	79.6	94.4	x	85.6	90.5	82.5	84.8	88.0	97.1	78.4	92.9
1991	82.8	94.0	x	89.3	91.1	81.8	84.4	87.5	101.9	84.7	96.3
1992	84.1	87.9	x	96.5	86.2	79.8	81.5	91.1	106.0	86.3	90.2
1993	88.2	83.2	x	106.4	82.3	80.1	80.6	96.3	110.8	89.2	84.2
1994	92.1	90.3	x	102.0	89.5	84.2	85.6	93.0	110.0	90.5	88.8
1995	95.6	94.1	x	101.7	93.6	88.4	89.8	93.8	108.7	91.3	89.8
1996	96.2	96.0	x	100.2	95.5	92.9	93.6	96.6	103.9	96.4	96.2
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	98.4	110.2	x	88.2	109.7	106.0	107.0	95.8	92.5	95.5	106.9
1999[p]	95.5	102.2	x	91.9	101.8	111.0	108.6	107.2	85.3	99.1	106.1
2000[p]	101.4	103.9	x	96.2	104.2	116.0	112.8	110.4	86.7	105.1	107.7

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 5b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Mining, Quarrying and Oil Well										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-1.9	-3.7	x	1.7	-2.2	8.2	6.1	11.8	-10.1	15.6	13.6
1983	6.9	-3.9	x	10.8	-2.7	5.0	3.6	8.9	1.9	7.6	-3.3
1984	9.9	5.5	x	4.4	6.4	3.9	4.3	-1.6	6.0	5.1	0.9
1985	6.0	3.8	x	2.2	4.7	4.9	4.8	1.1	1.1	4.5	2.3
1986	-5.0	-4.0	x	-1.0	-3.2	0.6	-0.3	4.6	-5.5	2.0	3.1
1987	4.4	-4.0	x	8.4	-3.6	-0.2	-1.1	3.8	4.6	0.2	-7.9
1988	8.9	3.3	x	5.5	4.2	0.5	1.5	-2.8	8.3	7.6	2.1
1989	-6.7	-0.5	x	-6.2	0.4	-1.0	-0.6	-0.5	-5.7	4.2	11.2
1990	-0.2	-2.4	x	2.2	-1.3	-0.7	-0.8	1.7	0.4	5.1	2.8
1991	4.0	-0.3	x	4.3	0.7	-0.9	-0.5	-0.6	4.9	8.1	3.6
1992	1.6	-6.6	x	8.1	-5.3	-2.5	-3.4	4.1	4.1	1.9	-6.3
1993	4.9	-5.3	x	10.2	-4.5	0.4	-1.1	5.7	4.5	3.3	-6.7
1994	4.5	8.6	x	-4.1	8.7	5.2	6.2	-3.4	-0.7	1.5	5.4
1995	3.8	4.1	x	-0.3	4.6	4.9	4.8	0.8	-1.1	0.8	1.1
1996	0.7	2.1	x	-1.4	2.1	5.0	4.2	3.0	-4.4	5.6	7.1
1997	3.9	4.1	x	-0.2	4.7	7.7	6.9	3.6	-3.8	3.8	4.0
1998[p]	-1.6	10.2	x	-11.8	9.7	6.0	7.0	-4.2	-7.5	-4.5	6.9
1999[p]	-3.0	-7.2	x	4.2	-7.2	4.7	1.4	12.0	-7.8	3.8	-0.7
2000[p]	6.2	1.6	x	4.6	2.4	4.5	3.9	2.9	1.7	6.1	1.5

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 6a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Manufacturing										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	67.8	100.7	81.7	67.4	89.0	73.0	82.6	74.0	93.4	49.6	73.7
1982	61.6	90.7	79.2	67.9	81.3	72.7	77.6	81.0	85.2	56.2	82.8
1983	64.6	89.5	84.2	72.1	80.8	70.4	76.5	79.5	92.1	60.2	83.4
1984	71.9	91.9	91.9	78.3	83.4	70.1	78.0	77.1	102.8	63.6	81.3
1985	75.9	94.6	93.9	80.4	86.4	72.5	80.8	77.4	105.1	66.3	82.6
1986	75.9	98.3	89.9	77.3	90.0	75.6	84.1	77.7	100.6	67.2	87.1
1987	78.9	102.0	89.6	77.4	93.9	78.6	87.7	77.9	100.6	68.8	89.0
1988	85.0	107.8	91.2	79.1	99.9	83.0	93.0	77.8	102.8	71.4	90.5
1989	87.2	106.9	91.5	81.6	99.9	87.5	95.0	82.7	99.7	76.1	93.3
1990	83.0	100.9	89.4	82.3	95.2	88.7	92.7	88.5	93.6	80.8	98.3
1991	77.6	92.4	88.1	83.9	88.1	88.4	88.0	95.7	87.8	86.8	103.4
1992	78.3	88.9	91.2	87.9	85.6	86.7	85.8	97.3	90.4	91.5	103.9
1993	82.9	89.0	96.2	93.0	86.7	85.3	86.0	95.7	97.2	93.3	100.1
1994	89.4	91.6	100.5	97.5	89.7	87.7	88.9	95.7	101.9	94.8	97.2
1995	93.7	94.6	101.5	99.0	93.3	91.2	92.4	96.2	102.9	97.0	97.9
1996	93.7	96.9	98.3	96.5	96.0	94.2	95.2	97.0	99.5	97.9	101.3
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	104.1	104.5	99.2	99.6	104.7	105.1	104.9	100.7	98.9	100.7	101.1
1999[p]	110.4	108.1	100.9	102.3	110.2	108.5	109.5	100.4	101.8	102.4	100.2
2000[p]	116.5	111.7	102.8	104.5	115.0	111.6	113.5	99.9	104.5	103.8	99.5

[p] The symbol p means that the series are preliminary.

Table 6b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Manufacturing										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-9.1	-9.9	-3.0	0.8	-8.6	-0.4	-6.1	9.5	-8.7	13.3	12.3
1983	4.9	-1.3	6.3	6.1	-0.6	-3.2	-1.4	-1.9	8.1	7.0	0.7
1984	11.2	2.7	9.2	8.6	3.2	-0.3	2.0	-3.0	11.6	5.7	-2.5
1985	5.6	2.9	2.1	2.7	3.6	3.4	3.5	0.4	2.2	4.2	1.5
1986	-0.1	3.8	-4.3	-3.9	4.1	4.2	4.2	0.4	-4.3	1.5	5.5
1987	4.0	3.8	-0.3	0.2	4.4	4.0	4.3	0.2	0.0	2.4	2.2
1988	7.8	5.7	1.7	2.2	6.4	5.6	6.1	-0.1	2.2	3.8	1.7
1989	2.5	-0.8	0.4	3.3	0.0	5.5	2.1	6.2	-3.0	6.5	3.1
1990	-4.8	-5.6	-2.3	0.9	-4.7	1.4	-2.4	7.0	-6.1	6.2	5.3
1991	-6.6	-8.5	-1.5	1.9	-7.5	-0.3	-5.0	8.1	-6.2	7.4	5.3
1992	1.0	-3.7	3.6	4.7	-2.9	-2.0	-2.6	1.8	3.0	5.4	0.4
1993	5.9	0.1	5.5	5.8	1.3	-1.6	0.3	-1.7	7.5	2.0	-3.6
1994	7.8	2.9	4.5	4.9	3.5	2.9	3.3	0.0	4.9	1.6	-3.0
1995	4.8	3.3	0.9	1.5	3.9	3.9	3.9	0.5	0.9	2.2	0.8
1996	0.0	2.4	-3.1	-2.4	2.9	3.3	3.1	0.9	-3.3	1.0	3.4
1997	6.7	3.1	1.7	3.6	4.2	6.2	5.0	3.0	0.5	2.2	-1.3
1998[p]	4.1	4.5	-0.8	-0.4	4.7	5.1	4.9	0.7	-1.1	0.7	1.1
1999[p]	6.1	3.4	1.7	2.7	5.3	3.2	4.4	-0.2	2.9	1.7	-0.9
2000[p]	5.5	3.4	1.8	2.2	4.3	2.9	3.7	-0.5	2.7	1.3	-0.7

[p] The symbol p means that the series are preliminary.

Table 7a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Construction										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	93.8	90.8	x	106.3	84.8	81.4	83.7	94.1	115.2	60.9	59.0
1982	92.7	79.9	x	117.8	75.2	81.4	76.6	105.4	113.8	67.5	58.2
1983	91.2	78.1	x	118.4	73.8	80.4	75.2	106.4	113.3	68.2	58.4
1984	87.2	79.1	x	111.9	74.4	80.2	75.7	104.9	108.6	68.0	61.7
1985	92.1	82.3	x	113.6	77.5	80.0	78.0	100.3	115.1	71.9	64.2
1986	96.3	85.0	x	115.1	80.1	82.0	80.5	99.7	117.3	74.9	66.1
1987	101.6	95.4	x	107.3	90.0	85.2	89.0	91.2	119.3	77.8	73.1
1988	104.7	103.2	x	101.8	97.7	89.2	95.9	88.1	117.3	81.6	80.4
1989	110.5	110.4	x	100.4	104.8	93.4	102.4	86.1	118.3	84.9	84.8
1990	110.1	109.0	x	101.3	104.0	95.2	102.2	88.9	115.5	89.0	88.1
1991	100.8	96.7	x	104.2	93.1	94.9	93.4	98.6	106.2	94.2	90.4
1992	94.7	94.0	x	100.8	91.4	95.1	92.0	101.6	99.5	94.6	93.9
1993	91.6	93.1	x	98.4	91.4	95.9	92.2	103.3	95.5	93.5	95.0
1994	94.5	97.7	x	96.7	96.5	97.2	96.6	99.6	97.2	90.8	93.9
1995	91.6	94.5	x	96.9	93.7	96.9	94.2	102.6	94.5	92.4	95.3
1996	94.8	95.6	x	99.2	95.1	96.9	95.3	101.5	97.8	93.8	94.5
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	100.0	101.3	x	98.7	101.0	103.4	101.4	102.1	96.6	105.0	106.3
1999p	104.2	108.7	x	95.6	108.9	107.2	108.6	98.4	97.1	103.7	108.2
2000p	107.6	114.9	x	93.3	114.1	110.9	113.6	96.2	96.9	108.2	115.5

p The symbol p means that the series are preliminary.
x The symbol x means that the series has been suppressed for quality reasons.

Table 7b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Construction										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-1.2	-12.0	x	10.8	-11.3	0.0	-8.4	12.0	-1.2	10.7	-1.4
1983	-1.7	-2.2	x	0.5	-2.0	-1.2	-1.8	1.0	-0.5	1.0	0.5
1984	-4.3	1.2	x	-5.5	0.9	-0.2	0.6	-1.5	-4.1	-0.2	5.5
1985	5.6	4.1	x	1.5	4.1	-0.3	3.1	-4.4	6.0	5.7	4.1
1986	4.5	3.2	x	1.3	3.4	2.6	3.2	-0.6	1.9	4.2	2.9
1987	5.5	12.3	x	-6.8	12.4	3.8	10.5	-8.5	1.7	4.0	10.7
1988	3.0	8.1	x	-5.1	8.5	4.7	7.7	-3.4	-1.7	4.8	10.0
1989	5.6	7.0	x	-1.4	7.3	4.7	6.7	-2.3	0.8	4.1	5.5
1990	-0.4	-1.3	x	0.9	-0.7	2.0	-0.2	3.2	-2.3	4.8	3.8
1991	-8.4	-11.3	x	2.8	-10.5	-0.3	-8.6	10.9	-8.1	5.9	2.6
1992	-6.1	-2.8	x	-3.2	-1.9	0.2	-1.5	3.1	-6.3	0.4	3.9
1993	-3.3	-0.9	x	-2.3	0.1	0.8	0.2	1.7	-4.1	-1.2	1.2
1994	3.2	4.9	x	-1.8	5.5	1.3	4.8	-3.6	1.8	-2.9	-1.2
1995	-3.1	-3.3	x	0.3	-2.9	-0.3	-2.5	3.0	-2.8	1.8	1.5
1996	3.5	1.2	x	2.3	1.5	0.0	1.2	-1.1	3.4	1.5	-0.8
1997	5.5	4.7	x	0.8	5.2	3.2	4.9	-1.5	2.3	6.6	5.8
1998[p]	0.0	1.3	x	-1.3	1.0	3.4	1.4	2.1	-3.4	5.0	6.3
1999[p]	4.2	7.3	x	-3.1	7.7	3.7	7.1	-3.6	0.5	-1.2	1.8
2000[p]	3.3	5.7	x	-2.4	4.9	3.5	4.6	-2.2	-0.2	4.3	6.7

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 8a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Transportation and Storage										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	57.3	85.2	77.6	67.2	76.1	66.9	73.2	80.9	86.0	59.7	87.8
1982	53.4	77.9	75.4	68.3	70.0	70.4	70.3	92.0	75.6	66.5	96.5
1983	56.7	74.7	81.2	75.4	67.7	72.0	69.3	97.9	78.7	70.8	92.9
1984	63.7	82.1	85.2	77.3	74.5	74.0	74.4	90.8	86.3	70.9	90.8
1985	67.0	85.5	86.6	78.0	78.0	74.6	76.9	87.9	89.9	73.2	92.9
1986	67.4	87.1	85.8	77.0	80.2	74.2	78.1	85.7	90.9	74.2	95.4
1987	71.8	86.7	91.9	82.5	80.2	73.2	77.7	85.0	98.1	76.8	92.3
1988	77.4	88.5	96.8	87.2	82.5	74.7	79.7	85.0	103.8	80.4	91.3
1989	77.4	92.9	92.5	82.9	87.1	76.6	83.3	82.9	101.2	80.7	96.5
1990	77.4	90.2	93.2	85.3	85.4	77.6	82.6	86.5	99.8	85.9	99.3
1991	70.0	86.3	85.5	80.7	82.3	80.2	81.5	93.0	86.9	90.8	111.2
1992	74.4	85.4	89.9	86.6	82.3	82.9	82.4	97.1	89.4	94.1	107.4
1993	78.8	89.8	90.2	87.4	87.6	86.2	87.0	96.0	91.2	91.9	103.9
1994	87.5	94.7	95.7	92.3	92.7	88.8	91.3	93.7	98.5	93.4	100.4
1995	91.1	96.6	96.6	94.2	95.7	91.4	94.2	94.5	99.6	97.6	103.1
1996	95.0	97.8	98.8	97.1	97.3	94.1	96.2	96.1	101.0	95.2	98.1
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998p	103.2	103.9	98.8	99.3	103.7	105.5	104.4	101.6	97.7	100.6	101.4
1999p	108.8	109.8	98.7	99.0	109.4	111.3	110.1	101.4	97.6	102.8	103.9
2000p	114.6	112.3	100.2	102.1	113.2	116.7	114.5	104.0	98.1	106.7	104.7

p The symbol p means that the series are preliminary.

Table 8b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Transportation and Storage										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-6.9	-8.6	-2.9	1.7	-8.0	5.2	-4.0	13.7	-12.0	11.5	9.9
1983	6.3	-4.1	7.7	10.4	-3.3	2.3	-1.5	6.4	4.0	6.4	-3.7
1984	12.4	9.9	4.9	2.5	10.1	2.7	7.5	-7.2	9.7	0.1	-2.3
1985	5.1	4.1	1.7	0.9	4.7	0.9	3.4	-3.2	4.1	3.3	2.3
1986	0.6	1.9	-1.0	-1.3	2.8	-0.6	1.6	-2.5	1.2	1.4	2.7
1987	6.5	-0.5	7.1	7.1	0.0	-1.4	-0.5	-0.8	7.9	3.5	-3.2
1988	7.9	2.1	5.3	5.8	2.8	2.0	2.5	0.0	5.8	4.6	-1.1
1989	0.0	5.0	-4.5	-5.0	5.6	2.5	4.5	-2.5	-2.5	0.5	5.7
1990	0.0	-3.0	0.8	3.0	-2.0	1.4	-0.8	4.4	-1.4	6.3	2.9
1991	-9.6	-4.2	-8.3	-5.4	-3.6	3.3	-1.3	7.6	-12.9	5.7	12.0
1992	6.3	-1.1	5.2	7.3	-0.1	3.4	1.0	4.4	2.9	3.7	-3.4
1993	5.9	5.1	0.3	0.8	6.4	4.0	5.6	-1.2	2.0	-2.4	-3.2
1994	11.1	5.4	6.1	5.7	5.9	3.0	4.9	-2.4	8.0	1.6	-3.3
1995	4.1	2.1	0.9	2.0	3.3	3.0	3.2	0.9	1.1	4.5	2.7
1996	4.3	1.2	2.2	3.1	1.7	2.9	2.1	1.7	1.4	-2.4	-4.8
1997	5.2	2.2	1.2	3.0	2.7	6.3	4.0	4.0	-1.0	5.0	1.9
1998[p]	3.2	3.9	-1.2	-0.7	3.7	5.5	4.4	1.6	-2.3	0.6	1.4
1999[p]	5.4	5.7	-0.1	-0.3	5.5	5.5	5.5	-0.2	-0.1	2.2	2.5
2000[p]	5.4	2.3	1.4	3.1	3.5	4.8	4.0	2.5	0.6	3.8	0.8

[p] The symbol p means that the series are preliminary.

Table 9a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Communication and Other Utility										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	61.5	79.7	93.7	77.1	70.5	63.2	65.9	79.3	98.4	57.2	74.2
1982	61.4	81.3	88.9	75.4	72.9	66.9	69.1	82.5	92.3	64.2	85.1
1983	64.1	81.3	90.1	78.8	73.8	69.8	71.3	86.1	92.5	68.2	86.5
1984	67.9	81.8	94.5	83.0	74.6	70.5	72.0	86.4	97.0	70.4	84.8
1985	72.1	83.5	99.0	86.3	76.6	70.9	72.9	85.1	102.4	72.9	84.4
1986	74.6	86.1	101.2	86.7	79.2	71.0	73.9	82.6	105.9	74.6	86.0
1987	77.4	87.7	102.6	88.3	81.2	72.7	75.7	82.9	107.4	76.9	87.2
1988	82.3	91.1	104.7	90.4	84.9	75.7	78.9	83.1	109.7	79.6	88.1
1989	83.8	94.7	101.0	88.6	88.7	80.1	83.2	84.8	105.3	82.0	92.6
1990	85.6	96.7	97.5	88.5	91.4	85.8	87.7	88.9	100.1	85.6	96.7
1991	89.5	97.7	97.3	91.6	93.3	91.4	92.0	93.8	98.1	92.4	100.9
1992	89.5	94.8	95.2	94.4	91.8	95.5	94.0	100.8	93.7	97.8	103.6
1993	90.1	96.4	94.1	93.4	94.6	96.5	95.7	100.2	93.4	99.5	106.5
1994	93.0	98.7	96.0	94.2	97.7	96.4	96.8	97.7	96.5	95.4	101.2
1995	96.7	101.1	98.3	95.7	100.8	97.1	98.4	96.1	99.7	98.0	102.4
1996	99.0	100.4	100.3	98.5	100.3	97.7	98.6	97.3	101.3	98.6	100.1
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	103.1	102.6	100.5	100.6	102.9	102.5	102.7	99.9	100.6	99.9	99.3
1999[p]	111.8	100.5	107.9	111.0	100.2	105.6	103.7	104.9	106.1	100.0	89.9
2000[p]	120.4	106.0	111.7	113.6	106.4	108.9	108.1	102.5	110.9	101.8	89.6

[p] The symbol p means that the series are preliminary.

Table 9b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Communication and Other Utility										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-0.2	2.0	-5.1	-2.2	3.4	6.0	4.9	4.0	-6.2	12.3	14.7
1983	4.5	0.0	1.4	4.5	1.3	4.3	3.1	4.3	0.2	6.2	1.6
1984	5.9	0.6	4.9	5.3	1.1	1.0	1.0	0.4	4.9	3.3	-1.9
1985	6.1	2.0	4.8	4.1	2.7	0.5	1.3	-1.5	5.5	3.5	-0.5
1986	3.6	3.1	2.2	0.4	3.4	0.2	1.3	-3.0	3.4	2.3	1.9
1987	3.7	1.9	1.4	1.9	2.5	2.3	2.4	0.4	1.4	3.2	1.3
1988	6.3	3.9	2.0	2.4	4.6	4.1	4.3	0.2	2.2	3.4	1.1
1989	1.9	3.9	-3.5	-2.0	4.6	5.9	5.4	2.1	-4.0	3.0	5.0
1990	2.1	2.2	-3.4	-0.1	3.0	7.0	5.5	4.8	-4.9	4.4	4.5
1991	4.6	1.1	-0.3	3.5	2.1	6.5	4.8	5.5	-2.0	7.9	4.3
1992	0.0	-3.0	-2.2	3.0	-1.6	4.5	2.2	7.5	-4.5	5.9	2.7
1993	0.7	1.7	-1.1	-1.0	3.0	1.1	1.8	-0.6	-0.4	1.8	2.8
1994	3.2	2.4	2.1	0.9	3.3	-0.1	1.2	-2.5	3.3	-4.2	-5.0
1995	4.0	2.4	2.4	1.6	3.2	0.7	1.6	-1.7	3.3	2.7	1.1
1996	2.3	-0.6	2.0	2.9	-0.5	0.7	0.3	1.3	1.6	0.7	-2.2
1997	1.0	-0.4	-0.3	1.5	-0.3	2.3	1.4	2.7	-1.3	1.4	-0.1
1998[p]	3.1	2.6	0.5	0.6	2.9	2.5	2.7	-0.1	0.6	-0.1	-0.7
1999[p]	8.4	-2.0	7.4	10.4	-2.6	3.0	1.0	5.0	5.4	0.1	-9.5
2000[p]	7.7	5.4	3.5	2.3	6.2	3.1	4.2	-2.3	4.6	1.8	-0.3

[p] The symbol p means that the series are preliminary.

Table 10a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Wholesale Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	46.9	72.7	74.0	64.2	64.2	60.2	63.0	83.0	77.6	47.6	73.8
1982	43.4	71.4	69.1	60.6	63.9	59.2	62.6	83.0	73.3	51.5	84.7
1983	47.5	70.9	75.5	66.7	64.0	58.8	62.5	83.1	80.6	56.0	83.6
1984	51.3	73.0	79.7	70.0	66.1	59.1	64.1	81.0	86.5	59.2	84.4
1985	57.0	74.7	86.3	76.2	67.9	61.1	65.9	81.8	93.4	63.1	82.7
1986	62.6	75.9	92.0	82.5	69.4	64.5	68.1	85.2	97.2	68.8	83.4
1987	67.8	79.5	94.4	85.3	73.3	68.1	71.9	85.9	99.8	75.2	88.2
1988	75.1	82.1	100.0	91.8	76.2	72.7	75.4	88.9	103.9	83.0	90.8
1989	79.8	86.5	100.1	92.7	80.8	77.7	80.1	90.2	103.3	86.0	93.2
1990	78.0	88.8	94.0	88.1	83.8	80.9	83.1	91.5	96.8	86.8	98.8
1991	77.9	85.4	95.3	91.4	81.5	82.4	81.8	96.8	94.7	89.6	98.2
1992	80.2	83.2	99.4	96.4	80.2	81.9	80.7	98.5	98.2	92.7	96.2
1993	82.0	82.5	100.4	99.3	80.5	85.3	81.8	103.5	96.2	93.9	94.6
1994	88.6	86.0	105.1	103.1	84.2	85.3	84.5	99.2	103.9	92.7	90.1
1995	89.8	90.2	100.9	99.5	89.0	88.9	89.0	98.5	101.0	95.5	96.0
1996	93.6	94.0	100.2	99.5	93.3	93.7	93.4	99.7	99.8	96.2	96.7
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	107.5	102.4	104.3	105.1	102.5	105.3	103.2	103.0	102.2	103.4	98.5
1999[p]	119.8	109.8	109.0	109.6	109.9	111.8	110.4	101.8	107.6	104.7	95.9
2000[p]	125.6	113.9	109.3	110.7	114.9	116.4	115.4	102.2	108.3	108.3	98.2

[p] The symbol p means that the series are preliminary.

Table 10b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Wholesale Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-7.4	-1.8	-6.7	-5.6	-0.4	-1.8	-0.7	0.0	-5.6	8.2	14.7
1983	9.3	-0.7	9.3	10.0	0.2	-0.7	0.0	0.0	10.0	8.7	-1.3
1984	8.0	3.0	5.5	4.9	3.2	0.6	2.5	-2.4	7.4	5.8	0.9
1985	11.2	2.3	8.3	8.9	2.7	3.3	2.9	1.0	7.9	6.5	-2.0
1986	9.8	1.6	6.6	8.2	2.2	5.7	3.3	4.1	4.1	9.0	0.9
1987	8.2	4.7	2.6	3.5	5.6	5.5	5.6	0.8	2.7	9.4	5.8
1988	10.8	3.3	6.0	7.5	4.1	6.8	4.8	3.5	4.0	10.5	2.9
1989	6.3	5.3	0.1	1.0	6.0	6.8	6.2	1.5	-0.6	3.5	2.6
1990	-2.2	2.7	-6.0	-4.9	3.7	4.1	3.8	1.4	-6.3	1.0	6.0
1991	-0.2	-3.9	1.4	3.7	-2.8	1.9	-1.6	5.8	-2.1	3.2	-0.6
1992	3.0	-2.5	4.3	5.5	-1.5	-0.7	-1.3	1.8	3.7	3.4	-2.1
1993	2.2	-0.8	0.9	3.0	0.4	4.2	1.3	5.0	-2.0	1.4	-1.6
1994	8.0	4.2	4.7	3.8	4.5	0.0	3.3	-4.1	8.0	-1.3	-4.8
1995	1.4	4.9	-4.0	-3.5	5.8	4.2	5.4	-0.7	-2.8	3.0	6.6
1996	4.3	4.2	-0.7	0.1	4.8	5.4	5.0	1.2	-1.1	0.7	0.7
1997	6.8	6.4	-0.2	0.5	7.2	6.7	7.0	0.3	0.2	3.9	3.5
1998[p]	7.5	2.4	4.3	5.1	2.5	5.3	3.2	3.0	2.2	3.4	-1.5
1999[p]	11.5	7.2	4.5	4.3	7.3	6.1	7.0	-1.1	5.3	1.3	-2.6
2000[p]	4.8	3.8	0.3	1.0	4.6	4.1	4.5	0.4	0.7	3.4	2.4

[p] The symbol p means that the series are preliminary.

Table 11a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Retail Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	67.3	80.3	95.6	83.5	73.9	55.6	70.2	69.5	122.4	56.5	67.5
1982	65.6	77.4	95.8	84.6	71.9	54.3	68.4	70.4	122.3	61.0	71.9
1983	66.4	78.6	95.1	84.2	73.5	54.4	69.6	69.5	123.4	62.3	73.7
1984	72.8	82.8	100.4	87.9	77.3	55.0	72.6	66.5	134.1	67.1	76.3
1985	78.1	87.4	102.3	89.4	81.7	57.3	76.4	65.5	138.4	69.8	78.0
1986	81.3	92.3	100.0	88.0	86.8	60.9	81.2	65.9	135.2	72.8	82.7
1987	84.5	92.3	102.1	91.4	87.3	65.1	82.7	70.5	131.2	80.0	87.4
1988	85.7	95.0	99.4	90.2	90.4	69.2	86.1	72.9	124.9	84.1	93.2
1989	86.9	95.3	99.4	91.1	90.9	72.5	87.3	76.2	120.5	88.6	97.1
1990	82.5	96.9	92.1	85.0	92.8	74.8	89.3	77.3	110.7	90.0	105.7
1991	79.1	93.0	90.3	84.9	89.9	76.4	87.4	82.0	103.9	94.9	111.5
1992	80.6	93.5	90.0	86.0	91.3	80.2	89.3	85.6	100.6	94.7	109.9
1993	83.1	93.2	91.6	89.0	91.8	85.2	90.5	91.2	97.5	96.1	107.8
1994	87.8	96.6	92.8	90.8	95.5	89.8	94.4	92.9	97.7	92.9	102.2
1995	91.4	98.1	94.9	93.0	97.1	92.5	96.2	94.3	98.7	93.2	100.1
1996	92.8	97.7	95.7	94.9	97.2	95.6	96.8	97.8	97.0	95.7	100.8
1997	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	104.8	100.5	103.4	104.3	100.2	105.7	101.4	105.2	99.1	104.7	100.5
1999[p]	110.1	101.7	106.3	108.3	101.2	112.9	103.6	111.1	97.3	104.3	96.4
2000[p]	116.6	103.0	109.1	113.4	103.8	120.0	107.1	116.7	97.1	108.5	95.7

[p] The symbol p means that the series are preliminary.

Table 11b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Retail Trade										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-2.4	-3.7	0.3	1.3	-2.8	-2.4	-2.7	1.3	0.0	7.8	6.4
1983	1.1	1.6	-0.7	-0.4	2.3	0.2	1.8	-1.3	0.9	2.1	2.6
1984	9.7	5.4	5.5	4.4	5.1	1.1	4.2	-4.3	8.6	7.7	3.4
1985	7.3	5.6	2.0	1.7	5.7	4.1	5.3	-1.5	3.2	4.0	2.3
1986	4.0	5.6	-2.3	-1.6	6.3	6.3	6.3	0.7	-2.3	4.3	6.0
1987	3.9	0.0	2.1	3.9	0.5	6.9	1.8	6.9	-3.0	9.9	5.7
1988	1.5	2.9	-2.7	-1.4	3.6	6.3	4.2	3.4	-4.9	5.2	6.6
1989	1.4	0.3	0.0	1.1	0.5	4.8	1.4	4.6	-3.5	5.3	4.2
1990	-5.1	1.7	-7.3	-6.8	2.1	3.1	2.3	1.4	-8.2	1.6	8.8
1991	-4.1	-4.0	-1.9	-0.1	-3.1	2.1	-2.2	6.1	-6.2	5.4	5.5
1992	1.8	0.6	-0.4	1.2	1.6	5.0	2.2	4.4	-3.2	-0.2	-1.4
1993	3.1	-0.3	1.7	3.5	0.6	6.2	1.4	6.6	-3.1	1.5	-1.9
1994	5.7	3.7	1.4	2.0	4.0	5.5	4.3	1.8	0.2	-3.3	-5.1
1995	4.1	1.5	2.2	2.5	1.7	3.0	1.9	1.5	1.1	0.4	-2.1
1996	1.6	-0.4	0.9	2.0	0.1	3.3	0.7	3.7	-1.7	2.7	0.7
1997	7.7	2.4	4.5	5.4	2.9	4.7	3.3	2.3	3.1	4.4	-0.8
1998[p]	4.8	0.5	3.4	4.3	0.2	5.7	1.4	5.2	-0.9	4.7	0.5
1999[p]	5.1	1.2	2.9	3.9	1.0	6.8	2.2	5.6	-1.8	-0.4	-4.0
2000[p]	6.0	1.2	2.6	4.7	2.6	6.2	3.4	5.0	-0.2	4.0	-0.7

[p] The symbol p means that the series are preliminary.

Table 12a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Finance, Insurance and Real Estate										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	76.3	x	x	63.8	52.0	56.9	67.8	121.3	42.4	x
1982	x	77.0	x	x	65.5	52.7	58.0	68.1	118.3	44.8	x
1983	x	79.1	x	x	68.1	55.6	60.8	69.9	115.7	45.5	x
1984	x	79.8	x	x	69.2	58.2	62.8	72.7	107.6	49.6	x
1985	x	79.5	x	x	69.6	62.0	65.3	77.7	109.0	55.2	x
1986	x	81.7	x	x	72.0	66.1	68.6	80.6	107.5	58.0	x
1987	x	85.5	x	x	76.0	72.8	74.2	85.1	101.7	63.5	x
1988	x	89.4	x	x	80.1	77.8	78.8	87.0	92.5	68.0	x
1989	x	91.5	x	x	82.7	83.7	83.2	91.5	87.1	71.7	x
1990	x	92.5	x	x	84.8	88.2	86.6	95.4	84.8	74.1	x
1991	x	93.1	x	x	86.6	90.8	88.8	97.8	84.3	78.9	x
1992	x	92.3	x	x	87.5	91.9	89.8	99.8	85.7	82.1	x
1993	x	93.3	x	x	90.3	92.1	91.2	98.9	89.3	84.6	x
1994	x	95.3	x	x	93.4	92.4	92.8	97.1	96.3	83.7	x
1995	x	94.0	x	x	92.9	95.1	94.1	101.2	96.6	86.5	x
1996	x	97.4	x	x	96.7	97.1	96.9	99.7	96.9	90.6	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998[p]	x	97.7	x	x	97.3	103.2	100.5	105.5	99.8	109.3	x
1999[p]	x	99.8	x	x	97.7	107.8	103.1	107.9	97.8	115.3	x
2000[p]	x	103.2	x	x	102.5	112.0	107.6	108.4	99.7	128.7	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 12b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Finance, Insurance and Real Estate										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	0.9	x	x	2.7	1.4	2.0	0.4	-2.5	5.6	x
1983	x	2.7	x	x	3.9	5.4	4.8	2.7	-2.2	1.7	x
1984	x	0.8	x	x	1.6	4.8	3.4	3.9	-7.0	9.0	x
1985	x	-0.3	x	x	0.6	6.6	3.9	6.9	1.3	11.3	x
1986	x	2.7	x	x	3.4	6.5	5.1	3.8	-1.3	5.1	x
1987	x	4.7	x	x	5.5	10.2	8.1	5.5	-5.5	9.4	x
1988	x	4.6	x	x	5.4	6.8	6.2	2.3	-9.0	7.1	x
1989	x	2.3	x	x	3.2	7.5	5.5	5.1	-5.8	5.5	x
1990	x	1.1	x	x	2.5	5.4	4.1	4.3	-2.6	3.4	x
1991	x	0.6	x	x	2.1	3.0	2.6	2.4	-0.7	6.4	x
1992	x	-0.8	x	x	1.0	1.2	1.1	2.0	1.8	4.0	x
1993	x	1.0	x	x	3.2	0.2	1.6	-0.9	4.1	3.1	x
1994	x	2.1	x	x	3.5	0.3	1.8	-1.8	7.9	-1.1	x
1995	x	-1.3	x	x	-0.5	2.9	1.4	4.2	0.4	3.4	x
1996	x	3.6	x	x	4.0	2.1	3.0	-1.4	0.2	4.8	x
1997	x	2.7	x	x	3.4	3.0	3.2	0.3	3.2	10.3	x
1998[p]	x	-2.3	x	x	-2.7	3.2	0.5	5.5	-0.2	9.3	x
1999[p]	x	2.2	x	x	0.4	4.4	2.6	2.3	-2.0	5.5	x
2000[p]	x	3.4	x	x	4.9	3.9	4.4	0.5	1.9	11.6	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 13a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Business Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	48.5	x	x	40.7	13.7	33.6	27.0	433.5	50.9	x
1982	x	47.8	x	x	41.2	13.8	34.0	27.6	447.6	57.9	x
1983	x	47.1	x	x	41.5	14.6	34.6	29.5	393.7	58.5	x
1984	x	50.8	x	x	45.1	16.4	37.8	30.9	380.8	61.0	x
1985	x	54.9	x	x	49.4	18.6	41.7	32.5	347.0	64.1	x
1986	x	60.2	x	x	54.5	21.1	46.2	33.8	332.3	65.1	x
1987	x	65.0	x	x	59.2	24.7	51.0	36.8	311.3	69.4	x
1988	x	70.0	x	x	64.3	29.1	56.3	40.5	289.2	76.2	x
1989	x	74.9	x	x	69.6	33.8	61.7	44.2	256.1	81.1	x
1990	x	75.3	x	x	70.8	37.1	63.6	48.3	235.5	87.3	x
1991	x	76.2	x	x	73.0	41.7	66.5	53.7	204.0	89.2	x
1992	x	73.6	x	x	71.6	49.1	67.1	65.0	159.6	92.5	x
1993	x	76.3	x	x	75.4	52.8	71.0	67.7	155.9	93.6	x
1994	x	79.8	x	x	79.5	64.3	76.7	79.2	131.0	95.1	x
1995	x	85.1	x	x	84.8	71.6	82.4	82.9	126.0	95.8	x
1996	x	92.0	x	x	91.5	84.9	90.4	91.7	107.0	95.9	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998p	x	109.8	x	x	109.8	121.0	111.5	111.2	87.4	105.3	x
1999p	x	121.7	x	x	120.0	147.7	124.1	123.6	75.5	107.3	x
2000p	x	127.4	x	x	128.8	177.9	135.8	143.2	67.5	124.4	x

p The symbol p means that the series are preliminary.

x The symbol x means that the series has been suppressed for quality reasons.

Table 13b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Business Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	-1.5	x	x	1.2	0.4	1.0	1.9	3.3	13.7	x
1983	x	-1.5	x	x	0.8	5.8	1.8	7.2	-12.0	1.1	x
1984	x	7.9	x	x	8.6	12.5	9.4	4.6	-3.3	4.2	x
1985	x	8.1	x	x	9.5	13.2	10.2	5.1	-8.9	5.1	x
1986	x	9.6	x	x	10.3	13.6	10.9	4.0	-4.2	1.6	x
1987	x	8.0	x	x	8.7	16.9	10.3	8.9	-6.3	6.6	x
1988	x	7.6	x	x	8.7	17.6	10.3	9.9	-7.1	9.7	x
1989	x	7.1	x	x	8.1	16.4	9.6	9.3	-11.5	6.4	x
1990	x	0.5	x	x	1.8	9.8	3.1	9.2	-8.0	7.6	x
1991	x	1.1	x	x	3.1	12.3	4.5	11.1	-13.4	2.3	x
1992	x	-3.4	x	x	-1.9	17.8	1.0	21.1	-21.7	3.6	x
1993	x	3.6	x	x	5.4	7.6	5.7	4.0	-2.3	1.2	x
1994	x	4.6	x	x	5.4	21.8	8.1	17.1	-16.0	1.6	x
1995	x	6.7	x	x	6.6	11.4	7.4	4.7	-3.8	0.7	x
1996	x	8.1	x	x	7.9	18.6	9.7	10.5	-15.1	0.1	x
1997	x	8.7	x	x	9.3	17.8	10.6	9.1	-6.5	4.3	x
1998[p]	x	9.8	x	x	9.8	21.0	11.5	11.2	-12.6	5.3	x
1999[p]	x	10.9	x	x	9.3	22.1	11.3	11.2	-13.6	1.9	x
2000[p]	x	4.6	x	x	7.4	20.4	9.4	15.8	-10.6	15.9	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 14a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Educational Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	22.0	x	x	17.7	22.3	17.7	153.7	120.7	59.2	x
1982	x	24.7	x	x	19.5	24.0	19.5	146.2	121.3	57.4	x
1983	x	29.2	x	x	23.0	27.1	22.9	138.4	110.9	53.0	x
1984	x	29.9	x	x	23.5	32.8	23.7	164.0	92.3	54.4	x
1985	x	32.0	x	x	25.3	39.3	25.8	185.1	73.7	55.0	x
1986	x	35.9	x	x	28.6	44.3	29.2	186.1	64.0	52.9	x
1987	x	40.9	x	x	31.4	50.7	32.2	187.3	53.2	47.0	x
1988	x	39.3	x	x	31.3	59.1	32.5	225.6	44.9	52.6	x
1989	x	37.5	x	x	30.7	63.8	32.1	254.1	41.6	59.0	x
1990	x	46.1	x	x	35.7	67.8	37.1	211.4	41.0	54.1	x
1991	x	43.9	x	x	34.4	74.7	36.2	243.0	34.0	60.8	x
1992	x	42.8	x	x	34.2	78.8	36.1	262.8	33.5	65.1	x
1993	x	53.3	x	x	42.4	82.3	44.3	209.9	32.2	55.9	x
1994	x	52.6	x	x	43.6	92.6	45.8	238.7	27.3	57.4	x
1995	x	55.2	x	x	45.2	94.0	47.5	230.8	27.0	54.7	x
1996	x	84.4	x	x	83.2	99.5	85.2	121.9	69.5	103.0	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998[p]	x	119.8	x	x	119.4	100.5	115.7	80.7	119.3	94.5	x
1999[p]	x	116.5	x	x	116.4	102.7	113.6	84.7	144.9	83.4	x
2000[p]	x	120.6	x	x	119.5	105.3	116.6	83.8	168.9	93.9	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 14b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Educational Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	12.4	x	x	10.1	7.6	9.9	-4.9	0.5	-3.0	x
1983	x	18.2	x	x	17.8	12.9	17.4	-5.3	-8.5	-7.7	x
1984	x	2.4	x	x	2.2	20.9	3.8	18.5	-16.8	2.7	x
1985	x	7.0	x	x	7.7	19.9	8.7	12.9	-20.2	1.1	x
1986	x	12.3	x	x	13.2	12.8	13.2	0.6	-13.2	-3.8	x
1987	x	13.7	x	x	9.9	14.3	10.3	0.6	-16.8	-11.1	x
1988	x	-3.7	x	x	-0.3	16.7	1.1	20.5	-15.6	11.8	x
1989	x	-4.7	x	x	-2.1	7.9	-1.3	12.6	-7.2	12.1	x
1990	x	23.0	x	x	16.4	6.2	15.4	-16.8	-1.5	-8.2	x
1991	x	-4.8	x	x	-3.6	10.2	-2.4	14.9	-17.0	12.3	x
1992	x	-2.6	x	x	-0.7	5.6	-0.2	8.1	-1.5	7.1	x
1993	x	24.6	x	x	24.2	4.4	22.6	-20.1	-3.9	-14.0	x
1994	x	-1.3	x	x	2.6	12.5	3.4	13.7	-15.3	2.6	x
1995	x	4.9	x	x	3.8	1.6	3.6	-3.3	-0.8	-4.7	x
1996	x	53.0	x	x	84.1	5.9	79.6	-47.2	156.9	88.5	x
1997	x	18.4	x	x	20.2	0.5	17.4	-18.0	43.9	-2.9	x
1998[p]	x	19.8	x	x	19.4	0.5	15.7	-19.3	19.3	-5.5	x
1999[p]	x	-2.7	x	x	-2.5	2.2	-1.8	5.0	21.5	-11.8	x
2000[p]	x	3.5	x	x	2.6	2.5	2.6	-1.0	16.6	12.6	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 15a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Health and Social Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	42.6	x	x	45.6	69.5	49.7	170.2	92.3	58.4	x
1982	x	45.6	x	x	49.1	70.2	52.7	160.2	93.4	64.1	x
1983	x	47.9	x	x	50.4	71.6	54.0	155.3	94.4	69.3	x
1984	x	51.6	x	x	55.7	73.0	58.6	146.4	96.0	73.2	x
1985	x	54.3	x	x	58.8	75.2	61.6	143.1	96.1	77.7	x
1986	x	56.8	x	x	59.2	77.7	62.4	141.2	97.8	78.8	x
1987	x	62.8	x	x	65.9	80.6	68.3	131.5	96.6	78.4	x
1988	x	69.6	x	x	72.7	83.1	74.3	121.3	97.9	78.3	x
1989	x	69.8	x	x	71.0	85.8	73.4	125.1	99.8	85.2	x
1990	x	73.5	x	x	75.4	88.3	77.5	121.9	100.6	90.3	x
1991	x	78.9	x	x	79.6	88.6	80.9	113.4	104.0	91.0	x
1992	x	82.2	x	x	82.1	89.7	83.2	110.1	105.6	94.2	x
1993	x	88.9	x	x	91.4	89.2	90.7	100.6	104.1	92.5	x
1994	x	90.2	x	x	90.8	92.1	90.7	102.2	102.3	94.3	x
1995	x	90.9	x	x	86.8	94.7	87.9	104.4	99.5	95.2	x
1996	x	93.4	x	x	90.3	96.2	91.1	103.2	97.8	97.7	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998[p]	x	96.9	x	x	101.8	102.2	101.8	105.3	100.0	109.8	x
1999[p]	x	108.6	x	x	113.5	104.8	112.3	95.3	99.1	100.4	x
2000[p]	x	112.8	x	x	116.9	107.4	115.5	93.9	98.7	108.9	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 15b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Health and Social Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	7.0	x	x	7.6	1.0	5.9	-5.9	1.1	9.7	x
1983	x	4.9	x	x	2.8	1.9	2.6	-3.0	1.1	8.2	x
1984	x	7.8	x	x	10.5	2.0	8.5	-5.8	1.7	5.6	x
1985	x	5.2	x	x	5.6	3.0	5.1	-2.2	0.1	6.3	x
1986	x	4.7	x	x	0.7	3.3	1.2	-1.3	1.7	1.4	x
1987	x	10.6	x	x	11.2	3.8	9.5	-6.9	-1.1	-0.5	x
1988	x	10.8	x	x	10.5	3.1	8.8	-7.7	1.3	-0.2	x
1989	x	0.2	x	x	-2.4	3.3	-1.2	3.1	1.9	8.8	x
1990	x	5.4	x	x	6.2	2.8	5.5	-2.5	0.8	6.0	x
1991	x	7.4	x	x	5.5	0.4	4.4	-7.0	3.4	0.8	x
1992	x	4.1	x	x	3.2	1.2	2.8	-2.9	1.6	3.5	x
1993	x	8.1	x	x	11.3	-0.6	9.0	-8.6	-1.4	-1.8	x
1994	x	1.5	x	x	-0.7	3.2	0.0	1.7	-1.7	1.9	x
1995	x	0.7	x	x	-4.3	2.8	-3.1	2.1	-2.7	1.0	x
1996	x	2.7	x	x	4.0	1.6	3.6	-1.1	-1.8	2.6	x
1997	x	7.1	x	x	10.7	3.9	9.8	-3.1	2.3	2.3	x
1998p	x	-3.1	x	x	1.8	2.2	1.8	5.3	0.0	9.8	x
1999p	x	12.1	x	x	11.6	2.5	10.3	-9.5	-0.9	-8.6	x
2000p	x	3.9	x	x	3.0	2.4	2.9	-1.4	-0.4	8.4	x

p The symbol p means that the series are preliminary.

x The symbol x means that the series has been suppressed for quality reasons.

Table 16a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Accommodation, Food and Beverage Services										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	x	81.5	x	x	77.6	57.8	72.3	71.4	167.7	53.2	x
1982	x	77.2	x	x	73.8	57.9	69.7	75.3	153.7	58.8	x
1983	x	80.1	x	x	76.6	58.8	71.9	73.6	148.2	60.0	x
1984	x	79.7	x	x	76.4	61.5	72.5	77.4	145.0	64.4	x
1985	x	83.0	x	x	79.0	65.6	75.5	79.3	141.2	67.5	x
1986	x	86.4	x	x	83.3	70.4	79.9	82.0	130.9	68.7	x
1987	x	93.1	x	x	89.9	77.7	86.6	84.0	120.4	68.8	x
1988	x	93.4	x	x	90.6	86.1	89.2	92.9	111.3	75.0	x
1989	x	97.2	x	x	94.7	93.3	94.0	96.8	109.0	81.1	x
1990	x	97.5	x	x	93.9	97.5	94.3	100.9	104.9	84.2	x
1991	x	91.7	x	x	88.9	102.5	91.5	112.0	85.5	87.1	x
1992	x	91.0	x	x	89.0	102.4	91.6	112.8	86.2	91.6	x
1993	x	94.5	x	x	93.2	102.1	94.9	108.1	88.6	90.8	x
1994	x	97.3	x	x	95.3	102.7	96.8	105.6	91.3	92.1	x
1995	x	97.1	x	x	96.0	99.3	96.7	102.3	97.6	96.4	x
1996	x	98.5	x	x	97.7	98.1	97.8	99.6	99.1	96.2	x
1997	x	100.0	x	x	100.0	100.0	100.0	100.0	100.0	100.0	x
1998p	x	107.0	x	x	105.9	101.4	105.0	94.4	105.5	100.2	x
1999p	x	108.2	x	x	107.1	104.6	106.6	96.3	104.3	100.0	x
2000p	x	113.1	x	x	110.6	107.5	110.0	94.6	105.1	103.5	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 16b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Accommodation, Food and Beverage Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	x	-5.3	x	x	-4.9	0.3	-3.7	5.6	-8.4	10.7	x
1983	x	3.8	x	x	3.8	1.6	3.3	-2.3	-3.6	2.1	x
1984	x	-0.6	x	x	-0.3	4.6	0.7	5.1	-2.2	7.3	x
1985	x	4.2	x	x	3.5	6.6	4.2	2.4	-2.6	4.8	x
1986	x	4.0	x	x	5.4	7.4	5.8	3.4	-7.3	1.7	x
1987	x	7.8	x	x	7.8	10.2	8.4	2.4	-8.1	0.2	x
1988	x	0.3	x	x	0.8	10.9	3.0	10.6	-7.5	9.0	x
1989	x	4.0	x	x	4.5	8.3	5.4	4.3	-2.1	8.0	x
1990	x	0.3	x	x	-0.9	4.5	0.3	4.2	-3.7	3.9	x
1991	x	-5.9	x	x	-5.3	5.2	-3.0	11.1	-18.5	3.5	x
1992	x	-0.8	x	x	0.2	-0.1	0.1	0.7	0.9	5.1	x
1993	x	3.9	x	x	4.7	-0.3	3.7	-4.2	2.7	-0.9	x
1994	x	2.9	x	x	2.3	0.6	1.9	-2.3	3.1	1.4	x
1995	x	-0.1	x	x	0.7	-3.3	-0.1	-3.1	6.9	4.7	x
1996	x	1.4	x	x	1.8	-1.2	1.1	-2.6	1.5	-0.2	x
1997	x	1.5	x	x	2.3	1.9	2.3	0.4	0.9	3.9	x
1998[p]	x	7.0	x	x	5.9	1.4	5.0	-5.6	5.5	0.2	x
1999[p]	x	1.2	x	x	1.1	3.1	1.5	2.0	-1.1	-0.2	x
2000[p]	x	4.5	x	x	3.3	2.7	3.2	-1.7	0.8	3.5	x

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 17a. Productivity and Related Measures, 1981-2000, Indexes 1997=100

	Other Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1981	66.3	64.4	x	104.3	60.3	40.9	53.4	63.2	170.1	53.6	52.0
1982	64.8	62.8	x	104.6	59.1	40.6	52.6	64.2	167.6	58.8	56.9
1983	64.3	65.2	x	99.6	61.2	42.9	54.8	65.3	157.0	60.0	60.9
1984	67.2	66.3	x	102.5	62.5	46.3	56.9	69.5	151.4	64.2	63.4
1985	71.6	74.5	x	96.5	69.3	52.4	63.4	69.9	141.7	64.5	67.1
1986	75.2	74.5	x	101.4	71.0	58.7	66.9	78.4	131.6	70.0	69.3
1987	78.4	78.2	x	100.6	74.6	67.2	72.2	85.8	118.1	73.7	73.5
1988	86.7	83.4	x	104.6	80.3	75.2	78.7	90.3	116.5	79.4	76.4
1989	86.6	84.8	x	102.7	82.7	81.5	82.3	96.4	106.6	81.7	80.0
1990	86.6	86.6	x	100.5	83.6	84.8	83.9	98.3	102.2	85.9	85.9
1991	84.8	85.0	x	100.4	82.1	84.3	82.7	99.5	100.8	89.9	90.1
1992	85.4	83.6	x	102.7	81.3	86.0	82.6	103.1	99.5	93.6	91.7
1993	87.1	88.6	x	98.6	85.6	89.6	86.7	101.3	97.3	90.8	92.4
1994	90.1	92.9	x	97.2	90.8	94.2	91.7	101.6	95.6	90.9	93.8
1995	93.4	93.6	x	100.0	92.4	93.1	92.6	99.6	100.2	95.2	95.5
1996	93.7	98.9	x	94.7	97.8	95.3	97.1	96.3	98.2	94.9	100.2
1997	100.0	100.0	x	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1998[p]	102.9	102.5	x	100.3	103.0	104.7	103.5	102.1	98.2	107.9	107.5
1999[p]	105.1	107.3	x	97.9	108.8	109.8	109.1	102.4	95.6	106.0	108.2
2000[p]	107.7	107.4	x	100.1	108.6	113.9	110.2	106.1	94.3	113.9	113.6

[p] The symbol p means that the series are preliminary.

[x] The symbol x means that the series has been suppressed for quality reasons.

Table 17b. Productivity and Related Measures, 1981-2000, Annual Percentage Change

	Other Service										
	Gross Domestic Product	Hours	Multifactor Productivity	Output Per Hour	Labour Input	Capital Input	Combined Input	Capital Services Per Hour	Output Per Unit of Capital Services	Hourly Compen-sation	Unit Labour Cost
1982	-2.2	-2.5	x	0.3	-1.9	-0.7	-1.6	1.7	-1.5	9.7	9.4
1983	-0.8	3.9	x	-4.8	3.6	5.5	4.1	1.6	-6.3	2.1	7.0
1984	4.5	1.7	x	2.8	2.0	8.1	3.8	6.4	-3.6	7.0	4.1
1985	6.6	12.4	x	-5.8	11.0	13.0	11.6	0.6	-6.4	0.5	5.9
1986	5.0	-0.1	x	5.0	2.5	12.1	5.4	12.2	-7.1	8.5	3.3
1987	4.3	5.0	x	-0.8	5.1	14.5	8.0	9.5	-10.3	5.3	6.0
1988	10.6	6.7	x	3.9	7.6	11.9	8.9	5.3	-1.3	7.8	3.9
1989	-0.1	1.6	x	-1.8	3.0	8.4	4.6	6.8	-8.5	3.0	4.8
1990	-0.1	2.1	x	-2.2	1.1	4.0	2.0	1.9	-4.1	5.1	7.4
1991	-2.0	-1.9	x	-0.2	-1.7	-0.6	-1.4	1.2	-1.4	4.7	4.9
1992	0.8	-1.6	x	2.3	-1.1	2.0	-0.2	3.6	-1.3	4.1	1.7
1993	1.9	5.9	x	-4.0	5.4	4.2	5.0	-1.8	-2.2	-3.0	0.8
1994	3.4	4.8	x	-1.4	6.0	5.1	5.8	0.3	-1.7	0.1	1.5
1995	3.7	0.8	x	2.9	1.8	-1.1	0.9	-2.0	4.8	4.7	1.8
1996	0.3	5.6	x	-5.3	5.9	2.4	4.9	-3.3	-2.0	-0.3	4.9
1997	6.7	1.1	x	5.6	2.2	4.9	3.0	3.8	1.8	5.4	-0.2
1998[p]	2.9	2.5	x	0.3	3.0	4.7	3.5	2.1	-1.8	7.9	7.5
1999[p]	2.2	4.6	x	-2.4	5.6	4.9	5.4	0.2	-2.7	-1.7	0.6
2000[p]	2.4	0.2	x	2.3	-0.1	3.8	1.1	3.6	-1.3	7.4	5.0

[p] The symbol p means that the series are preliminary.
[x] The symbol x means that the series has been suppressed for quality reasons.

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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.

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