Catalogue no. 15-206-XIE — No. 006
ISSN: 1710-5269
ISBN: 0-662-44607-0

Research Paper

The Canadian Productivity Review

Investment and Long-term Productivity Growth in the Canadian Business Sector, 1961 to 2002

by John R. Baldwin and Wulong Gu

Micro-economic Analysis Division
18th Floor, R.H. Coats Building, Ottawa, K1A 0T6

Telephone: 1-613-951-4636

Statistics Canada Statistique Canada

Canada

How to obtain more information

Specific inquiries about this product and related statistics or services should be directed to Media Hotline, Communications Division, Statistics Canada, Ottawa, Ontario, K1A 0T6 (telephone: 613-951-4636).

For information on the wide range of data available from Statistics Canada, you can contact us by calling one of our toll-free numbers. You can also contact us by e-mail or by visiting our website.

National inquiries line	1-800-263-1136
National telecommunications device for the hearing impaired	1-800-363-7629
Depository Services Program inquiries	1-800-700-1033
Fax line for Depository Services Program	1-800-889-9734
E-mail inquiries	infostats@statcan.ca
Website	www.statcan.ca

Information to access the product

This product, catalogue no. 15-206-XIE, is available for free. To obtain a single issue, visit our website at www.statcan.ca and select Publications.

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable, courteous, manner. To this end, the Agency has developed standards of service which its employees observe in serving its clients. To obtain a copy of these service standards, please contact Statistics Canada toll free at 1-800-263-1136. The service standards are also published on www.statcan.ca under About us > Providing services to Canadians.

The Canadian Productivity Review

The Canadian Productivity Review is a series of applied studies that address issues involving the measurement, explanation, and improvement of productivity. Themes covered in the review include, but are not limited to, economic performance, capital formation, labour, prices, environment, trade, and efficiency at both national and provincial levels. The Review publishes empirical research, at different levels of aggregation, based on growth accounting, econometrics, index numbers and mathematical programming. The empirical research illustrates the application of theory and techniques to relevant public policy issues.

The primary distribution medium for this series is the Internet. These studies can be downloaded from the Internet at www.statcan.ca for free.

All papers in *The Canadian Productivity Review* go through institutional review to ensure that they conform to Statistics Canada's mandate as a government statistical agency and adhere to generally accepted standards of good professional practice.

The papers in the series often include results derived from multivariate analysis or other statistical techniques. It should be recognized that the results of these analyses are subject to uncertainty in the reported estimates.

The level of uncertainty will depend on several factors: the nature of the functional form used in the multivariate analysis; the type of econometric technique employed; the appropriateness of the statistical assumptions embedded in the model or technique; the comprehensiveness of the variables included in the analysis; and the accuracy of the data that are utilized. The peer group review process is meant to ensure that the papers in the series have followed accepted standards to minimize problems in each of these areas.

Statistics Canada

Investment and Long-term Productivity Growth in the Canadian Business Sector, 1961 to 2002

John R. Baldwin and Wulong Gu

Published by authority of the Minister responsible for Statistics Canada

June 2007

Catalogue no. 15-206-XIE, no. 006
Frequency: Occasional

ISSN 1710-5269
ISBN 0-662-44607-0

Ottawa

Authors' names are listed alphabetically.

La version française de cette publication est disponible (n° 15-206-XIF au catalogue, n° 006).

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued cooperation and goodwill.

Table of contents

Abstract

This paper employs the databases that are used to construct Statistics Canada's Productivity Accounts to examine the sources of growth in the Canadian economy and the history of productivity growth in Canada over the period 1961 to 2002. It makes use of a new time series using the North American Industry Classification System. The growth accounting system provides the framework for the analysis. This framework provides estimates of the relative importance of labour inputs, investments in capital, and productivity growth. The data that are required to address this issue also allow changes in the composition of capital and labour inputs to be investigated. In addition, the underlying factors that determine labour productivity (multifactor productivity, capital deepening, and increases in skill level) are outlined. Since the database is constructed at the industry level, all these relationships can be pursued both at the level of the total economy and for individual industries.

Keywords: productivity, investment, technological progress

Executive summary

This paper makes use of the databases at the heart of the Canadian Productivity Accounts to examine the sources of growth in the Canadian economy and the history of productivity growth in Canada over the period from 1961 to 2002. It employs new time series using the North American Industry Classification System.

The growth accounting system provides the framework for the analysis. This analysis, based on a production framework, decomposes output growth into the portion that comes from increases in labour and capital and a residual (entitled multifactor productivity) that captures the component that is not directly related to the increasing use of labour and capital.

Measures of multifactor productivity (MFP) growth are often used to assess the rate of growth of technological progress. They are of intrinsic interest because consumers benefit directly from higher productivity growth in terms of lower prices. Baldwin et al. (2001) show that on a cross-section basis, industries with higher multifactor productivity growth have the lowest rate of price increases. Successful productivity growth also affects an industry's international competitive advantage. Baldwin and Yan (2006) demonstrate that, at the industry level, changes in the relative Canada–U.S. price are inversely related to estimates of changes in relative multifactor productivity in Canada and the United States.

The growth accounting framework provides estimates of the relative importance of labour inputs, investments in capital and productivity growth. The data that are required to address this issue also allow changes in the composition of capital and labour inputs to be investigated. In addition, the underlying factors that determine labour productivity (multifactor productivity, capital deepening, and increases in skill level) can be measured. Since the database is constructed at the industry level, all these relationships can be pursued both at the level of the total economy and for individual industries.

Several questions are posed in this section of the paper.

1. What has been the history of productivity growth over the period?

Estimates of annual productivity growth have fluctuated considerably over time. They are quite volatile in the short run. They are often high at the end of the business cycle and fall during recessions and slowdowns. This makes interpretation of short-run trends difficult. Moreover, short-run averages are extremely sensitive to the choice of endpoints. Analysts who wish to argue that crises exist can use the high points just before the end of a business cycle and the low points at middle of recessions.

There are, however, discernible long-run trends in Canadian productivity growth—both labour and multifactor productivity. There was a long decline from the early 1960s to 1990. Since then, productivity growth has picked up. The break point appears to correspond with the start of the 1990s—the decade when investments in information and communications technologies (ICT) began to receive so much attention. It is significant that both productivity and output growth trends are correlated. Higher output growth is generally accompanied by higher productivity

growth. This could either be because high growth periods make the introduction of new technologies easier or that rapid technological change fans higher growth rates.

A word of caution is, however, required here. High output growth rate industries are not necessarily those industries with the highest labour productivity growth. At the industry level, high growth does not necessarily translate into higher productivity or vice versa.

2. What types of capital are used in the growth process?

In 2002, the largest component of aggregate capital services was machinery and equipment (M&E) outside of information and communications technologies (non-ICT M&E), followed by building structures and engineering structures. Non-ICT M&E accounted for 27.0% of aggregate capital services in 2002, building structure capital accounted for 24.3% of aggregate capital services, while engineering structure capital, 18.3% of capital services. It should be noted that the latter two made up over 42.0% of the total—much more than the machinery and equipment component. Capital consists of a great deal more than machinery and equipment—and most of the capital that workers have to work with comes in forms other than machinery and equipment.

The share of capital input accounted for by non-ICT machinery and equipment remained virtually unchanged over time. The share of the remaining assets (building structures, land and inventories) declined during the period from 1961 to 2002. The decline in inventory's share has been associated with the application of 'just-in-time' production methods. The decline for buildings and engineering structures has been the result of long-term increases in capital productivity in those sectors that make the most use of this type of infrastructure investment—transportation, communications, utilities, and water (see Baldwin and Dixon, 2007).

There has been a long-term shift in capital services towards machinery and equipment and away from structure capital, land and inventories in the Canadian business sector. Of machinery and equipment capital, ICT increased the most. Over the period from 1961 to 2002, ICT capital increased at an annual rate of 14.1%. The dramatic increases in ICT capital services occurred as the price of ICT capital declined relative to other forms of capital. Canadian businesses have made large investments in ICT to take advantage of the dramatic decline in the price of ICT capital.

3. What types of labour are used in the growth process?

Since 1961, the composition of the labour force has changed dramatically (Gu et al. [2002]). From 1961 to 1979, the share of younger workers (less than 25 years) first increased dramatically and then fell continuously until the mid-1990s. As this group of post-war boomers aged, workers in the age group from 25 to 44 years, increased from the 1970s to the early 1990s and then declined. This long demographic cycle led first to a decline in the average experience of the workforce and more recently to an increase.

There have also been dramatic changes in the educational qualifications of the labour force. The percentage with only high school has fallen steadily, and those with post-secondary degrees has

increased. For example, those with some post-secondary education increased from less than 10% in 1961 to over 40% by 2000.

The declining average age occasioned by additions of relatively large portions of younger workers early in the period, and then an increase in experienced workers later as these workers matured, led to quite opposite effects on the contribution to labour inputs that came from upgraded skills—what is termed 'labour composition' in this paper. The effect of the changing level of experience occasioned by first a greening of the labour force and then its aging follows an inverted U—with first a decline coming from the experience component then an increase.

But the impact of changing experience in most periods is small. Far more important is the increase in the skill component that comes from increases in education levels. And since upgrading of education levels is more or less continuous during the period, this force provided most of the increase caught by the labour composition or quality component of labour input growth.

4. What is the relative contribution of capital, labour and productivity growth to economic growth?

The growth accounting framework decomposes output growth into three components—the growth in labour inputs, the growth in capital inputs and multifactor productivity (MFP). Output needs labour and capital inputs and growth in output can be constrained by shortages of either of these factor inputs. In a world where population growth is constraining future increases in employment, maintaining present growth rates will depend on whether growth rates in capital or multifactor productivity can be accelerated. Historical experience may give some indication of the possibilities for substitution here.

For the period from 1961 to 2002, output grew 3.9% per year in the business sector. Capital services contributed 1.8 percentage points or 47.3% of the business sector output growth. Labour input contributed 1.5 percentage points or 38.1% of the output growth. A good portion of the growth in both labour and capital came from changes in the composition of each aggregate—that is, the composition of the inputs changed from the less productive to more productive inputs over the period. The growth that is due to upgrading accounted for about one-third of total growth for both labour and capital.

Multifactor productivity growth was the least important source of output growth in the business sector and contributed 0.6 percentage points or 14.6% of the output growth. The growth in capital services then has been more important than the growth of labour over most of the period and offers possibilities for compensating for future reductions in the growth in labour that are expected to result from declining population growth in Canada.

Many factors influence the rate of growth in labour inputs—changing socio-economic factors that lead to higher labour force participation by women, increases in participation by older males, and immigration. Over the period studied, the growth rate in employment has decreased slowly. If these declines continue in the future, overall growth may fall unless capital or MFP growth increases. However, the historical record does not show that either of these components have

increased enough over the last three decades to offset the decline in labour growth that has already occurred. The contribution made by the growth in capital has fallen over the period—by even more than the contribution of labour growth—starting in the 1980s and continuing into the 1990s. The residual, unmeasured category (multifactor productivity growth) has also declined since its high point in the 1961 to 1973 period—though, there is evidence this decline reached its low point at the end of the 1980s and has recently begun to rise.

Nevertheless, the average growth in multifactor productivity over most of the period has not been large—especially compared to the growth in labour inputs. And it is less obvious that increases in this component are likely to offset future declines in the growth of labour.

For those who wish to compare Canadian MFP estimates to those of other countries, it should be remembered that the Canadian Productivity Accounts calculate the labour and capital inputs with 'quality' components included. That is, the Accounts do not just sum hours worked across all groups of workers or sum capital across all asset types. The Accounts calculate weighted averages of the growth in hours worked using 56 different categories of workers and 28 different types of assets. By doing so, the Canadian Productivity Accounts take into account the different productivity of inputs. The difference between the weighted growth rate of the different inputs and the simple sum of all hours or all capital is referred to as the effect of the changing composition of labour or capital—the labour and the capital composition effect, respectively. This procedure yields substantially higher estimates of the growth in factor inputs (labour and capital) and concomitantly lowers estimates of multifactor productivity growth.

For example, the labour composition effect averaged 0.7% annually from 1961 to 2002. This translates into an average of about 0.5% annually when multiplied by the share of labour to give the contribution to output growth of shifts in labour composition towards more skilled workers. The same capital composition effect averaged around 1.5% per year, which is about 0.6% per year when multiplied by capital's share, to give the contribution that shifts in capital composition to more productive assets had on output growth. If these two composition effects were added back into the multifactor productivity estimate of 0.6% annually, the uncorrected multifactor productivity estimate would increase to 1.6% per year—an increase of almost 300%. It is important then to take into account the heterogeneity of factor inputs—for it changes the conclusions that can be drawn from the growth accounting framework. We conclude here that most of the growth came from increased factor inputs—not from disembodied technological progress. If we had not corrected for the changing quality of factor inputs, we would have drawn the opposite conclusion.

If we are to rely on higher rates of multifactor productivity growth in the future to maintain economic growth rates, we need to forecast whether increases are possible and whether they are sustainable. The historical record does not suggest large increases are likely. It also does not suggest they are very sustainable. The contributions of labour and capital are much more stable than is multifactor productivity. Multifactor productivity growth is largest in the 1961-to-1973 period. It is lowest in the 1979-to-1989 period. The growth in capital services, though in decline, was generally more important than the growth in labour services. Together the growth rates in these two factor inputs have contributed over 1.0 percentage points of the 2.3 percentage points decline in output between the periods from 1961 to 1973 and 1973 to 2002. The rest of the

decline comes from a much lower growth in multifactor productivity. However, between the 1980s and 1990s, while the growth in labour and capital inputs declined, multifactor productivity increased enough to substantially offset these declines.

5. How important are the various factors that determine the growth in labour productivity?

Growth in labour productivity is of interest because it is closely connected with changes in real wage rates over the long run.

For the 1961-to-2002 period, labour productivity grew at annual rate of 2.2% in the business sector. Capital deepening was the most important factor. It contributed 1.2 percentage points and 53.2% of the labour productivity growth. The change in labour composition was an important source of labour productivity growth in the business sector for the 1961-to-2002 period, contributing 0.5 percentage points or a quarter of labour productivity growth in the business sector. A positive labour composition effect captures the increase in the average educational attainment and experience levels of the workers. The importance of the labour composition component therefore demonstrates that investments in education and training have made a significant contribution to labour productivity growth in Canada.

The contribution of ICT capital deepening to labour productivity growth showed a large increase over time. In the 1961 to 1973 period, little of capital's contribution to labour productivity was from ICT investment. In the 1989 to 2002 period, about 58.6% of the productivity contribution of capital services can be attributed to ICT capital deepening. And it is significant that it is during the latter period that multifactor productivity growth has once more picked up. This has been used by some to suggest that it is not so much increases in capital intensity as the type of capital that matters.

Multifactor productivity growth contributed the remaining 0.6 percentage points or 26.1% of labour productivity growth. MFP growth is often associated with technological change, organizational change, scale economies or changes in utilization rates.[1] While contributing substantially to labour productivity growth, its importance is nevertheless, in this framework, behind investment in general. But this type of conclusion needs to be qualified. The growth accounting framework decomposes contributions from different factors into separate and independent components for the purposes of simplicity. In the end, the types of technological change embedded into the multifactor productivity measure is no doubt a function of investments in new technologies, in new organizational forms, in new ways of doing business, and in research and development. A more detailed set of measures in all of these areas would just expand the list of types of capital assets that are behind technological progress.

In two of the periods, capital deepening and multifactor productivity have moved together. From 1961 to 1973, the contribution from both was high. From 1979 to 1989, both declined relative to earlier periods. This suggests that there are particular time periods when it is technology that is

1. The studies on the determinants of productivity growth suggest that there is complementarity between physical capital, human capital and technical process (Organization for Economic Co-operation and Development [OECD], 1991; Gera, Gu and Lee, 1998). The normal growth accounting framework for examining the sources of labour productivity growth does not allow for this complementarity.

being driven by investment in the type of traditional assets that are measured in capital stock. In other periods (1973 to 1979), capital deepening is high but multifactor productivity was nevertheless lower, thereby suggesting that traditional investments were not sufficient conditions in this sense for technological progress—that there may have been deficiencies in this period in the complementary expenditures that are required for change.

6. What are the differences in growth profiles at the industry level?

This paper also examines industry performance using the growth framework at the industry level. It asks whether the trends depicted at the level of the total economy are widespread or concentrated only in the largest industries. The investigation posed several questions:

6.1 Does most productivity growth come from one sector?

At the industry level, goods industries tend to have higher productivity growth than the services sectors. But there are exceptions to the rule. Information industries have had some of the highest growth rates both in terms of labour and multifactor productivity. The information sector has benefited from the ICT revolution (Beckstead and Gellatly, 2003).

Over the entire period, high growth rates can be found in both goods and services—in information and transportation on one side and in manufacturing and agriculture on the other. Agriculture continues to shine in terms of productivity growth—a phenomenon that has continued throughout most of this century.

High growth occurs both in new economy and old economy industries. There are no easy generalizations about where productivity growth and technological change are highest. This suggests that technological advances are neither easy to predict nor easy to classify. They occur at different times, in different places.

6.2 Is the importance of capital accumulation uniform across industries?

The economy is made up of industries that range from highly capital intensive to more labour intensive. Capital accumulation is the dominant source of output growth in the two natural resources industries (mining and oil and gas extraction; and utilities), as would be expected. But the other sectors where capital is important are the finance, insurance and real estate industries. Labour input is the most important contributor to output growth in professional services, and education and health care services industries. Those two industries are labour-intensive industries. But even there, capital is an important source of output growth. In the professional services industries, the contribution to output growth from labour was 3.1 percentage points, compared with 3.0 percentage points from capital, 2.5 percentage points from intermediate inputs, and -1.9 percentage points from MFP growth. The two distributive trades industries (retail and wholesale) have relatively higher contributions from labour than capital.

6.3 Is capital deepening the prime contributor to labour productivity growth?

The contributions to labour productivity growth differ substantially across industries. In some, capital deepening is the dominant contributor to labour productivity growth. But in these industries, there is no consistent pattern as to whether multifactor productivity growth makes higher or even positive contributions to labour productivity growth. Increasing the quality of the labour force is important in most industries—though less important than MFP growth in most industries. And there is less variability across industries in the contribution of skill upgrading than there is in either capital deepening or in MFP growth. The growth in the knowledge economy is being felt across all industries (see Baldwin and Beckstead, 2003).

6.4 How do the new economy industries differ from the old economy industries?

The share of new economy industries in the business sector is small and has shown little change over time. Over the period from 1961 to 2002, new economy industries accounted for between 7% and 8% of nominal gross domestic product (GDP) in the Canadian business sector. Natural resource industries were more important than new economy industries in terms of their contribution to nominal GDP in Canada. In 2002, the natural resource sector accounted for 18.8% of nominal GDP in the total business sector. New economy industries had the highest labour productivity and multifactor productivity growth over the period from 1961 to 2002 period. Natural resource industries had the second-highest labour productivity growth, but in this sector multifactor productivity growth is lower than that of the other business sector industries. Investment and capital deepening is a more important source of output and productivity growth in natural resource industries than in new economy industries. Technological progress has been more rapid in new economy industries than in natural resource industries.

6.5 Are fluctuations in the total economy's productivity growth coming primarily from one sector?

Productivity fluctuations at the level of the aggregate economy cannot be attributed to a particular sector or a particular industry throughout the period. The identity of individual industries, whose productivity growth rates decline, changes over periods—thereby indicating that the changes that are occurring are idiosyncratic and industry specific. Technological change does not have its impact felt consistently across the industry set.

1. Introduction

Productivity is one of several key indicators of the economic health of an economy. It provides a measure of the productive capability of the economy—how much output an economy produces for a specific amount of resources that it devotes to production. In the long run, the country's living standard is related to productivity growth (Baldwin et al., 2001, Chapter 1).

In the past few years, attention has focused closely on the productivity growth acceleration after the mid-1990s and subsequent slowdown after 2000 (Rao, Sharpe and Smith, 2005; Robidoux and Wong, 2003; Sharpe, 2002). However, the estimates of productivity growth are highly volatile (Baldwin et al., 2001, Chapter 1). This volatile nature of productivity growth suggests that one should not read too much into productivity growth in the short run. Productivity slowdowns often occur in the trough of an economic cycle and pick up at the end of a business cycle. Therefore, we should examine the trend productivity growth and its underlying sources over longer periods—either full cycles or even longer periods.

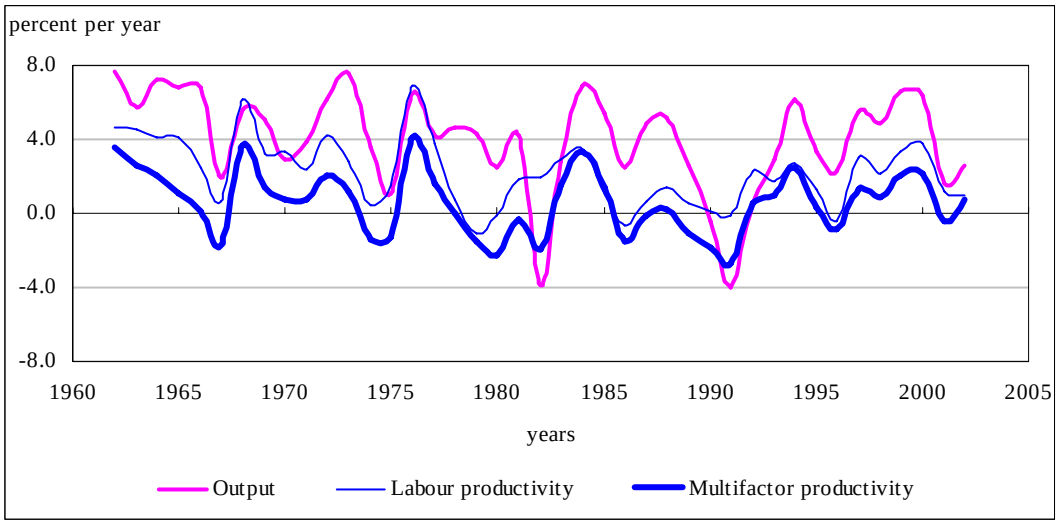
This paper has three main objectives. First, it provides a comprehensive overview of trend labour productivity growth in the Canadian business sector over the period from 1961 to 2002. Second, it examines the contribution of investment in tangible assets and human capital and multifactor productivity growth to trend labour productivity growth. Third, it analyses the industrial sources of the aggregate productivity growth. A focus is on the contribution that various goods and services sectors make to aggregate productivity growth. As there is a continued interest in the role that new economy industries and (old economy) natural resource industries play in Canadian economic growth, this paper also examines the relative contribution that these two sectors make to aggregate productivity growth.

The short-term labour productivity growth rates can be thought of as originating from underlying productivity growth trend and a cyclical component (Figure 1a). Over a business cycle, the cyclical components tend to be offsetting, with cyclical upturns cancelling out cyclical downturns so that the actual productivity growth between two cyclical output troughs (or peaks) tends to be equal to trend productivity growth.

To examine trend productivity growth, we need to choose periods between two cyclical output troughs (or peaks).[2] For the purpose of this paper, we will focus on four sub-periods, 1961 to 1973, 1973 to 1979, 1979 to 1989 and 1989 to 2002.[3] The actual productivity growth estimated for those periods should be less influenced by short-run cyclical factors and thus, should reflect trend productivity growth. A comparison of average productivity growth between those four periods should reveal whether there are changes in trend productivity growth over time.

2. See Cross (1996) for various measures of business cycles in Canada.
3. The last business cycle started around 1989 and ended around 2000. We have added years 2001 and 2002 to that period for the analysis.

Figure 1a
Annual output and productivity growth in the business sector, 1962 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

The analysis in this paper is based on the Capital, Labour, Energy, Material and Services (KLEMS) industry productivity database for the period 1961 to 2002. The data base is based on the North American Industry Classification, and is developed at Statistics Canada. The methodology for constructing the database is documented in Baldwin and Harchaoui (2002).

The next section presents the growth accounting framework that has been developed by Jorgenson (1966) and Jorgenson and Griliches (1967).[4] Section 3 examines the trend in output and productivity growth in the aggregate business sector over the period from 1961 to 2002. It also analyzes the sources of output growth and labour productivity growth in the business sector. In Section 4, we examine the contribution of different industries to aggregate productivity growth. In Section 5, we conclude the paper.

2. Background

We examine several different concepts in this paper—the growth in labour productivity, the growth in multifactor productivity, and the contribution that different inputs make to the growth process. This section describes how each are related to one another.

2.1 The growth accounting framework

The common thread to all three concepts is the growth accounting framework that relates changes in output to changes in factors of production such as labour, capital, materials and other inputs to the production process.

4. The recent contributions to the growth accounting framework include Schreyer (2001), Diewert (2004), and Baldwin and Gu (2007).

The microeconomic theory of the firm uses a 'production function' to formally describe the relationship between the services of inputs and output.[5] Economists have formalized this using a production function relating output to factors of production (labour and capital).

(1) $Q = F(X_1, X_2, ...X_n, t)$ where X_i represents the *i*'th input and t is time.

The components of the growth in output can be investigated using the total differential of (1) with respect to time, that is

(2) $$\frac{dQ}{dt} = \sum \frac{\partial F}{\partial X_i}\frac{dX_i}{dt} + \frac{\partial F}{\partial t}.$$

Equation (2) tells us that output changes can be divided into the underlying components using an accounting identity. The first part is the contribution that increases in labour or capital would be expected to make to output growth. It is just the existing marginal product of labour (capital) multiplied by the change in labour (capital) devoted to production. In addition, output would be expected to increase if the production function shifts outwards over time for various reasons, for example, from improvements in technology or other organizational changes that allow the resources that are used in production to produce more than they did previously.

At any point in time, existing techniques allow additional factor inputs (labour, capital) that are applied to the production process to produce additional output. The product of additional factors that are added to the production process times the existing marginal product of those factors provide an estimate of the expected amount of output in a given period. If actual output exceeds this, productivity is said to have increased.

Dividing both sides of (2) by Q gives

(3) $$\frac{dQ}{dt}.\frac{1}{Q} = \frac{1}{Q}.\frac{\partial F}{\partial t} + \sum \frac{\partial F}{\partial X_i}\frac{dX_i}{dt}\frac{1}{Q_i}.$$

Now if we define multifactor productivity growth as

(4) $M\dot{F}P = \frac{1}{Q}.\frac{\partial F}{\partial t}$ and recognizing that $\frac{dX_i}{Qdt} = \frac{X_i}{Q}\dot{X}_i$ (where $\dot{X}_i = d\ln X_i$ is the rate of growth in the *i*'th input) gives

(5) $$\dot{Q} = M\dot{F}P + \sum \frac{\partial F}{\partial X_i}\frac{X_i}{Q}\dot{X}_i.$$

5. Alternately, theorists sometimes start with a cost function to derive a measure of multifactor productivity.

That is, the rate of output change is equal to the rate of growth in multifactor productivity and a component that depends on the rate of growth in factor inputs. The latter term depends also on the marginal product of each factor as well as the term $\frac{X_i}{Q}\ \dot{X}_i$.

This framework can be used to measure $M\dot{F}P$ (the growth in multifactor productivity) if measures of the terms $\frac{\partial F}{\partial X_i}\frac{X_i}{Q}$ can be found since output change ($\dot{Q}$) and input change ($\dot{X}_i$) are produced in Canada by the Industry Accounts Division of the System of National Accounts Branch.

In order to find a way to proxy the remaining components, the first order conditions for profit maximization are invoked. In those situations where firms operate by hiring factors so that their marginal cost is just equal to their marginal product:

(6) $\frac{\partial C}{\partial X_i} = \frac{\partial F}{\partial X_i} P$ where P is the price of Q and C is total cost ($\equiv \sum P_i X_i$).

Recognizing $P_i = \frac{\partial C}{\partial X_i}$ and substituting into Equation (5) gives

(7) $\dot{Q} = M\dot{F}P + \sum \frac{P_i X_i}{PQ}\dot{X}_i = M\dot{F}P + \sum s_i \dot{X}_i$,

where s_i is factor *i*'s share in output (PQ).

If the production function is characterized by constant returns to scale and prices of factors (labour and capital) equal their marginal revenue product, then the share of labour in GDP and the share of capital in total product just exhaust total GDP. If not, then the formula has to be modified to

(8) $\dot{Q} = M\dot{F}P + \sum \varepsilon_{cy}^{-1} \frac{P_i X_i}{C} \dot{X}_i$,

where ε_{cy} is the measure of the scale of production (the cost elasticity of output).

This approach allows the statistician to approximate the contribution that each of the factors make to increases in output in Equation (7) using factor prices and the share of a factor in output. While a simplification of real world processes, its appropriateness depends not on whether it is a simplification, but rather on whether it is adequate for the purposes at hand.[6]

6. See Baldwin, Gaudreault and Harchaoui (2001) for an illustration of the parametric approach to productivity measurement that removes the effect of scale economies and market imperfections. Once done, the estimate of multifactor productivity so produced varies only slightly from the non-parametric estimate that makes the simplifying assumptions of constant returns to scale.

The productivity gains represented by the multifactor productivity (MFP) term occur because producers manage to find more efficient ways of producing goods. These gains originate from many sources—from technological change, organizational change, and from exploiting scale economies.

2.2 Multifactor productivity derived from growth accounting

Multifactor productivity (MFP) growth measures have been developed as summary statistics to measure the amount of those gains that cannot be attributed to factor inputs. In practice, they are calculated using Equation (7) as the difference between the rate of growth of output and the contribution to this growth of the increase in factor inputs, that is:

$$(9) \qquad \dot{MFP} = \dot{Q} - \sum \frac{P_i X_i}{PQ} \dot{X}_i = \dot{Q} - \sum s_i \dot{X}_i \, .$$

2.3 Relationship between multifactor productivity and labour productivity

While the growth Equation (9) forms the heart of growth accounting, other relationships are sometimes derived from this framework to examine subcomponents.

For example, labour productivity and multifactor productivity are directly related. This can be seen using Equation (9) and rewriting with two factors of production—labour (L) and capital (K).

$$(10) \qquad \dot{MFP} = \dot{Q} - s_l \dot{L} - s_k \dot{K} \, .$$

Then adding and subtracting $\dot{L}$ and rearranging gives

$$(11) \qquad \dot{MFP} = \dot{Q} - \dot{L} + \dot{L} - s_l \dot{L} - s_k \dot{K} = \dot{Q} - \dot{L} + (1 - s_l)\dot{L} - s_k \dot{K} \, .$$

Making use of the identity that $\sum s_i = 1$,

$$(12) \qquad \dot{MFP} = \dot{Q} - \dot{L} + (s_k)\dot{L} - s_k \dot{K} = \dot{Q} - \dot{L} + (s_k)(\dot{K} - \dot{L}) \, .$$

Recognizing that the rate of growth in labour productivity (LP) is

$$(13) \qquad \dot{LP} = \frac{dQ/L}{dt} . \frac{1}{Q/L} = \dot{Q} - \dot{L} \, .$$

And the rate of change in the capital/labour ratio is

$$(14) \qquad \frac{dK/L}{dt} . \frac{1}{K/L} = \dot{K} - \dot{L} \, .$$

Then Equation (12) tells us that

(15) $$\dot{LP} = \dot{MFP} + s_k \frac{\dot{K}}{L}.$$

In other words, the growth in labour productivity is equal to the growth in multifactor productivity plus the growth in the capital/labour ratio weighted by the share of capital in gross product. Labour productivity is thus higher when multifactor productivity is higher and the amount of capital that workers have to utilize is larger.

Alternately, Equation (10) can be modified by using the identity $\dot{Q} = s_l\dot{Q} + s_k\dot{Q}$. Then rearranging terms gives

(16) $$\dot{MFP} = \dot{Q} - s_l\dot{L} - s_k\dot{K} = s_l\dot{Q} - s_l\dot{L} + s_k\dot{Q} - s_k\dot{K} = s_l(\dot{Q} - \dot{L}) + s_k(\dot{Q} - \dot{K}).$$

Then since the rate of growth in capital productivity is

(17) $$\dot{KP} = \frac{dQ/K}{dt} \cdot \frac{1}{Q/K} = \dot{Q} - \dot{K},$$

Equation (16) can be written as

(18) $$\dot{MFP} = s_l(\dot{LP}) + s_k(\dot{KP}),$$ where $\dot{KP}$ is the capital productivity growth.

Thus, the growth in multifactor productivity is just the weighted average of the growth in labour productivity and the growth in capital productivity.

The Canadian productivity accounts break down the components of labour and capital inputs into different types. The Canadian Productivity Accounts break labour down into 56 components and capital into 28 asset types, and weight the growth in each type separately (see Gu, et al., 2002; Harchaoui et Tarkhani, 2002). The rate of growth of each input component is weighted by its share of factor income (wages and capital income, respectively) that is calculated using wage rates of each labour type and unit capital costs for each asset type. This procedure results in a rate of increase in labour and capital input that is substantially higher than the unweighted sum of all labour or all capital and thus, a lower estimate of multifactor productivity.

The equation used to estimate multifactor productivity in the Canadian Productivity Accounts takes into account the heterogeneity of both labour and capital and uses the following formula:

(19) $$\dot{MFP} = \dot{Q} - \sum\nolimits_i s_i \sum\nolimits_j \left(\frac{w_i^j X_i^j}{\sum w_i^j X_i^j} X_i^j\right),$$

where w_i^j is the cost of factor *i* of type *j* (the wage rate for each type of labour and the user cost of capital for each type of capital) and s_i is the share of each factor (labour and capital) in total GDP. Rewriting gives

$$(20) \qquad \dot{MFP} = \dot{Q} - \sum_i s_i \sum_j \left(\frac{w_i^j X_i^j}{\sum w_i^j X_i^j} \dot{X}_i^j\right) = \dot{Q} - s_l \dot{L} - s_k \dot{K},$$

where $\dot{L}$ and $\dot{K}$ are just the weighted average growth rates of the individual components of *L* and *K* as outlined in Equation (19).

Since labour productivity is usually calculated using the unweighted growth in hours worked ($\dot{H}$), that is,

$$(21) \qquad \dot{LP} = \dot{Q} - \dot{H}.$$

Then Equation (15) becomes

$$(22) \qquad \dot{LP} = \dot{MFP} + s_k \frac{\dot{K}}{L} + (\dot{L} - \dot{H}) = MFP + s_k \frac{\dot{K}}{H} + s_l \frac{\dot{L}}{H},$$

where H is just the rate of change of hours worked summed across all labour categories.

Equation (22) indicates that the growth in labour productivity can be broken into three components—the growth in multifactor productivity, a term involving the growth in capital intensity (capita per hour worked) and the labour composition term—the difference between the labour input as calculated here and the simple growth in hours worked that does not consider the difference in 'quality' of workers.

In summary, use of the production growth accounting framework allows several relationships to be examined. First, it allows us to examine the relative contribution of labour, as opposed to capital, to output growth, as shown in Equation (7). Investments in machinery and equipment, buildings and engineering structures are often perceived to be important and this framework permits a quantification of that importance in a systematic fashion.

Second, this framework permits an estimate of the importance of the residual, which has come to be referred to as multifactor productivity. Multifactor productivity captures the influence of many factors. When the estimate of the effect of increases in labour and capital are derived from assuming that there are constant returns to scale in the production process and that inputs are generally paid their marginal revenue product, the residual captures any economies of scale that are really present along with the effect of technological progress (that is, shifts in the production possibilities curve). When scale effects are relatively small, the estimate of multifactor productivity essentially captures technological progress. Technological progress allows an economy to produce more with the same or less resource inputs.

While the multifactor measure is often used to understand how efficiency is improving in the overall economy, it is not the only productivity measure that is frequently used to assess the amount of productivity gain in the economy. Labour productivity (output per worker or per hour worked) is also often used. The growth accounting framework can be used to understand how the two are related and what is causing divergences between them. As Equation (18) demonstrates, multifactor productivity is just a weighted average of the two partial productivity measures—labour and capital productivity. Multifactor productivity is, therefore, a more comprehensive measure than either labour or capital productivity in that it takes into account the efficiency with which the economy is transforming both labour and capital into output. Labour productivity is a partial measure since it examines only the efficiency with which the economy transforms one factor—labour.

The accounting framework with the appropriate transformations also yields Equation (15) that expresses labour productivity as a function of multifactor productivity and changes in the capital/labour ratio. This equation tells us that labour productivity will generally be greater than multifactor productivity—by an amount that depends partially on the rate at which the amount of capital per worker is increasing, partly on the capital intensity (as measured by capital's share) of the economy.

Each of Equations (7), (15) and (18) are identities. They are derived from the same framework—though they express the relationships in different ways. The first breaks down the growth in output into two components—the amount that comes from labour and capital and the residual, which is used to represent underlying change in the production process, part of which comes from technological improvements. During this process, the capital/labour ratio often changes (increases) and so too does labour productivity and capital productivity. These variables taken together satisfy the relationships expressed in Equations (15) and (18). Labour productivity will be higher when multifactor productivity is higher because they both embody technical change. But because of identities, labour productivity is also affected by increases in the capital/labour ratio.

Similarly, the equation for multifactor productivity states only that with increases in labour productivity and capital productivity, we should expect to see increases in multifactor productivity.

While these equations are only identities, they are nevertheless useful—since they allow us to parse out these relationships. They allow us to measure the relative importance of the various subcomponents.

This framework allows us to ask the following types of questions.

First, we can ask how much growth comes from applying more inputs (and what sort of inputs are more important) as opposed to the residual multifactor productivity term. This is important for those who believe the residual term captures externalities that are unrelated to labour or capital accumulations or the manner in which capital is combined with labour—because the residual, by the nature of the production process that is assumed, is essentially disembodied (what economists refer to as neutral technological progress). That is, the shift in the production function does not depend on the particular expansion path followed with regards to capital and labour.

Summary statistics, such as multifactor productivity, are more suitable for some purposes than others. They always need to be interpreted in context of the uses to which they are to be put. A summary statistic that is meant to capture long-term trends but that is volatile in the short run should be used to summarize long-run history, not short-run experience. And most summary statistics stem from an analytical or theoretical framework that abstracts from some aspects of reality, that simplifies reality so that it can be summarized in equation form. For some applications, these simplifications may not be appropriate.

Multifactor productivity measures are not different in this regard from other summary statistics. As we will show below, annual productivity growth rates are volatile, but long-run moving averages do show distinct trends and therefore provide useful information in this area. And most statistical agencies calculate them using non-parametric techniques that make very specific simplifying assumptions. For some purposes, these assumptions may be adequate; for others, they are not. For example, the Canadian estimate assumes constant returns to scale. It can be shown, therefore, that the MFP measure estimated without allowance for economies of scale subsumes any effects of scale economies in the estimates of changes in productivity over time. This is a problem for those who want to separate scale effects. It is not for those who believe they should be included in the host of causes behind changes in efficiency. And even if we wanted to separate out these effects, we would have to trade off our ability to produce a statistic that is more suitable for this purpose against the likelihood that an alternate measure will be less accurate because the size of scale economies is notoriously difficult to estimate.

A second example of a simplification that is not unimportant is the nature of technological progress that is assumed in the standard formulation. Technological progress is regarded as a shift in the production function that is not related to the way in which labour and capital are being combined—that the proportionate rate of increase in the amount of output obtained by using a given amount of labour and capital is independent of the amount of labour and capital. This may not be the case. Those who estimate multifactor productivity and then regress it on differences in factors used are essentially testing whether this assumption is correct.

Second, the equations that are associated with the growth accounting framework also allow us to investigate the extent to which labour productivity is higher or the same as multifactor productivity and how much of the difference can be attributed to the fact that the economy is capital intensive (has a large share of output accounted for by the services yielded by capital) or has an increasing capital/labour ratio. Labour productivity is often associated with real wage gains in the long run. Understanding then whether increases in labour productivity come from multifactor productivity (possibly the technological component) or from increasing capital investments per unit of labour input helps the analyst to understand and to quantify the various forces that are work.

Third, the growth accounting framework allows us to characterize how partial productivity measures (labour productivity and capital productivity) change over time—and what is apparently behind the changes in multifactor productivity. It allows those who want to know whether most of the partial productivity growth is coming from the labour or capital side.

None of this reveals the key to success—what drives investments, what causes technological advances—but it does allow a country's growth process to be tracked over time and compared to other countries (at least when the estimates from other countries are similar). Judicious analysis of these trends combined with outside information on technological advances and innovations provide an understanding of the reasons for economic success.

2.4 Data and methodology revisions

In this paper, we make use of a new Capital, Labour, Energy, Material and Services (KLEMS) database back to 1961 that has been built using the North American Industry Classification System (NAICS). Previously, the underlying database that was used for estimates of multifactor productivity (MFP) was constructed up to 1997 using the Standard Industrial Classification (SIC) system and since then using the NAICS. For the purposes of time series continuity, new estimates using the NAICS have been backcast to 1961. In order to do this, industries that had been originally defined using the old SIC system had to be split into parts to reflect the NAICS. This was relatively easy to do in 1997 because most of the source data had been double coded to both classification systems in that year. This allows splitting ratios to be developed for the sources in that year—GDP and its components, labour and investment. These splitting factors could also have been used for previous years. But errors would have been introduced in doing so, unless the components remained relatively similar over time. Unfortunately, the changing importance of industries makes this unlikely. Therefore, the Canadian System of National Accounts decided to use the commodity data that are available in its system of input/output tables to develop a methodology that allows for changing splitting ratios over time. These were used to develop estimates of GDP, labour and investment that were compatible over time.[7]

At the same time, the Canadian Productivity Accounts have taken the opportunity to introduce a number of improvements into their database.

First, data on labour input for the non-business sector have been revised to make them more compatible with the GDP estimates for this sector. Non-business GDP is estimated primarily from the wages and salaries of this sector—along with a small amount of returns to capital that are measured using estimates of depreciation. In this world, labour productivity estimates should be essentially zero.[8] Previous estimates have used the Labour Force Survey (LFS) to calculate jobs and hours worked in the non-business sector. However, non-business sector GDP is calculated using the Public Institutions Division's estimate of public sector employment. The new estimates presented here make use of these estimates along with data from the LFS on hours worked per person in the public sector to estimate hours worked in the non-business sector.

7. Other data are available from the Labour Force Survey on labour and from the Investment and Capital Stock Division that use fixed weights that are not compatible with the GDP data that are used here.
8. It will not be completely zero, because wages are used to estimate the major component of non-business sector and the wage per person is used as deflator. To the extent that hours worked per person have fallen, estimated labour productivity will increase. It should also be noted that if the imputed rent to owner-occupied dwellings is included in the non-commercial sector, productivity growth will be greater than zero because no data on hours is available for this sector.

Second, changes were made to existing industry series to remove discontinuities that existed as a result of breaks in data sources that had been used to estimate GDP series. Changes in commodity classification systems in 1980 and 1987 had resulted in discontinuities that our research had turned up.

Third, with the development of provincial labour productivity accounts, new benchmarks for the level of labour inputs have been developed that were introduced into the KLEMS data base. These benchmarks include changes in the source data (with an increased use of the Survey of Employment, Payrolls and Hours for industry estimates) and changes in the number of holidays built into the hours-worked estimates.

Fourth, assumptions about the share of labour going to the self-employed have been modified to reflect changes that occurred during the 1990s. In the past, it was assumed that the self-employed essentially earned incomes similar to the employed. While the Census of Population up to 1990 showed this was a reasonable assumption, during the 1990s, self-employed income fell behind that of production workers (see Baldwin and Chowhan, 2003). In the new productivity accounts, the wage or income going to the self-employed comes directly from the census and the Labour Force Survey. It is assumed that the hourly earning of self-employed workers is proportional to that of paid workers with the same level of education and experience. The proportional or scaling factor is based on the relative hourly earnings of paid and self-employed workers from the Census of Population.

Fifth, improvements have also been made on the capital stock side. Investment is now benchmarked on the estimates of investment included in the input-output tables. New estimates of depreciation have been incorporated into estimates of capital services (see Micro-economic Analysis Division, 2007). A revised methodology is used to measure the stock of land that is included in the capital stock.

3. Output growth and productivity growth in the business sector

3.1 Trend in output growth and productivity growth in the business sector

Trend output and productivity growth can be estimated as average growth rates over periods between benchmark years that represent the same stage of the business cycle. This detrending method is called the trends-trough-benchmark or TTB method (Gordon, 2003). Table 1 presents annual growth rates of the business sector output, labour productivity, capital productivity and multifactor productivity for four such periods that lie between cyclical output troughs: 1961 to 1973, 1973 to 1979, 1979 to 1989, and 1989 to 2002. The numbers in the table can be interpreted as trend growth rates.[9] Figure 2 plots those growth rates. It is apparent that both output growth and productivity growth fell over time. It is only in the last period graphed that the downward decline in productivity growth has been reversed.

9. Baldwin et al. (2001) uses a similar periodization to examine long-term trend productivity growth in the business sectror.

Table 1
Output and productivity growth in the business sector, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Real GDP[1]	3.87	5.46	3.96	3.22	2.86
Labour productivity	2.16	3.50	2.00	1.30	1.66
Capital productivity	-0.82	-0.27	-2.03	-1.23	-0.44
Multifactor productivity	0.56	1.44	0.22	-0.09	0.42

1. Gross domestic product.
Source: Statistics Canada, Canadian Productivity Accounts.

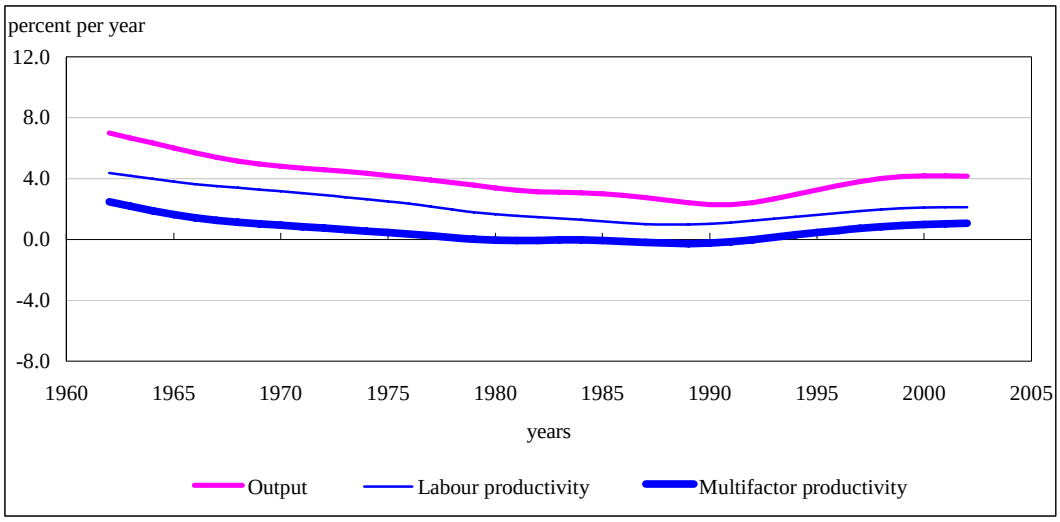
A look at long-term trends reveals a familiar feature of output and productivity growth in the Canadian business sector (Baldwin et al., 2001, Chapter 1). After strong output and productivity growth in the 1960s and early 1970s, output growth and productivity growth slowed markedly through the 1980s, with labour productivity growth declining from 3.5% before 1973 to 2.0% and 1.3% in the 1973-to-1979 and 1979-to-1989 periods, respectively, and multifactor productivity growth declining from 1.4% in the 1961-to-1973 period to 0.2% and -0.1% in the 1973-to-1979 and 1979-to-1989 periods, respectively.

The productivity growth slowdown after 1973 is not unique to Canada. It occurred in most countries that are members of the Organization for Economic Co-operation and Development (OECD). A large number of studies have examined the productivity growth slowdown for the period from 1973 to 1989 (e.g., OECD, 1991; Sharpe, 1998; Gera, Gu and Lee, 1998). Those studies provided a long list of explanations including rising energy prices, high inflation, rising taxes, growing government, deteriorating labour skills and depleted opportunities for inventions.

One explanation is that the lower productivity growth in the 1970s and 1980s was not really a slowdown; rather it was just returning to earlier levels. The high productivity growth in the 1960s and early 1970s is the effect of the unprecedented factors that came together to boost productivity growth in the immediate post-war period: rapid capital formation, introduction of new technologies and increased international trade (Sharpe, 1998).

Since 1989, the business sector in Canada has undergone a resurgence with accelerating growth in labour productivity and multifactor productivity. Annual labour productivity growth increased from 1.3% in the 1979-to-1989 period to 1.7% in the period 1989 to 2002. Annual multifactor productivity growth rose from -0.1% to 0.4% between those two periods.

Figure 1b
Trend output and productivity growth in the business sector, 1962 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

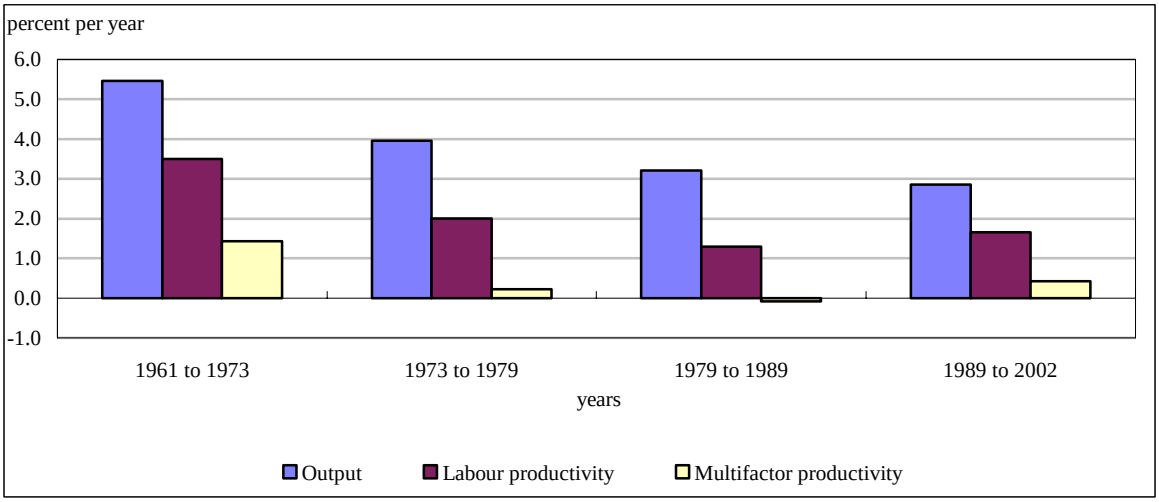
The trend output growth and productivity growth in Table 1 is estimated using the TTB method of detrending. The trend growth rates can also be estimated using formal statistical techniques such as Hodrick-Prescott (H-P) filter or structural break tests. Figure 1b plots the H-P trend output and productivity growth rates in the business sector.[10] Overall, the results from the H-P filter and TTB method reveal similar trends in output and productivity growth in the business sector. The growth in output and productivity continuously declined before 1989. Since then, productivity growth and output growth has accelerated in the business sector.

Van Norden (2005) uses structural break tests and finds that there is robust and significant evidence for a break in trend productivity growth in 1988. The evidence is consistent with our finding that trend productivity growth showed a break around 1989 and it accelerated after 1989 in the business sector.

A number of recent studies have focused on the productivity growth pick-up in the second half of the 1990s. As this productivity growth pickup occurred during the latter part of an expansion period of the recent business cycle, it was not a particularly rare event. A productivity acceleration of similar magnitude occurred in the other expansionary periods such as the early 1970s, the mid-1970s, and the early 1980s. The evidence in this paper and in van Norden (2005) suggests that a structural break in trend productivity growth occurred around 1989 in the Canadian business sector. In 1989, productivity growth of the business sector reversed the declining trend and started accelerating.

10. We have set lambda equal to 100 for the H-P filter.

Figure 2
Annual growth of output and productivity in the business sector, selected periods, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

3.2 The sources of output growth and labour productivity growth in the business sector

In this section, we use standard growth accounting techniques to quantity the contributions to output growth and labour productivity growth from increased inputs of capital and labour services, as well as the residual called multifactor productivity (MFP) growth.

Key to both decomposition exercises are measures of capital and labour. We discuss the course of growth in both these areas.

3.2.1 Capital services

Baldwin and Gu (2007) and Harchaoui and Tarkhani (2002) have documented the methodology and data sources for constructing capital services for multifactor productivity measures in Canada. Here, we mention three empirical issues related to the estimation of capital services.

First, aggregate capital services in the business sector are constructed using the so-called 'bottom-up approach'.[11] This bottom-up approach involves three steps. These are the estimation of capital stock, the aggregation of capital stock of various asset types within each industry to estimate industry capital services, and the aggregation of capital services across industries to derive capital services in the business sector.

11. The U.S. Bureau of Labor Statistics uses a similar approach to construct aggregate capital services in their business sector multifactor productivity measures.

Baldwin and Gu (2007) find that there is a large variation in the endogenous rate of return across industries and the endogenous rate of return is positively correlated with capital stock growth across industries. This suggests that the difference in the rate of return across industries is real, and capital tends to move towards those industries that earn relatively high rates of return. In these cases, it has been argued that we should use the industry-specific return to calculate the user cost of capital and that aggregate capital services should then be calculated by aggregating capital services across industries (Jorgenson, Gollop and Fraumeni, 1987). This approach takes into account the difference in the rate of return across industries and avoids the assumption of perfect mobility of capital inputs across industries.

The second empirical issue involves the way in which we have dealt with negative capital service prices during the estimation procedure. This arises from negative capital income in some periods in a few industries. Capital income is calculated from the input-output system as a residual, and is the difference between nominal value added and labour compensation of paid workers and self-employed workers. Negative capital income and negative capital service prices make aggregation difficult. More importantly, it is not clear that they are in keeping with the spirit of the estimation procedure outlined in the first section. Enterprises are assumed to hire factors to bring the marginal product into equality with these prices. In the case of labour contracts, it is clear what the relevant price is for short-term decisions on hiring. But in the case of capital, the expected long-run capital cost is the relevant concept and short-run fluctuations in return may not heavily influence long-run expectations.

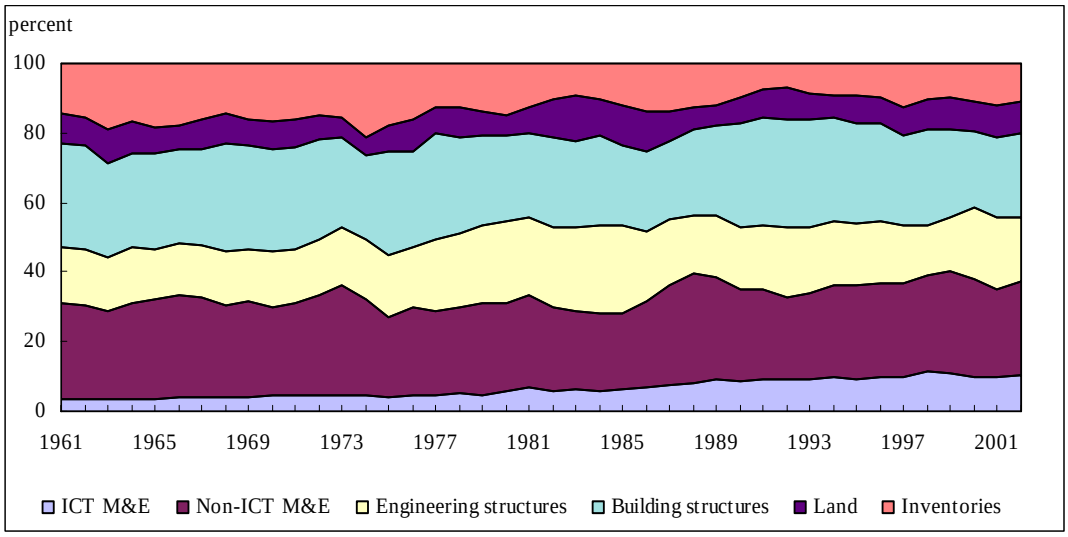
Therefore, to construct aggregate capital service input from asset-level capital stock and service prices, we have made adjustments for those assets whose user costs turn negative in the short run. We have set the user costs of those assets equal to the average user costs across all industries for those assets that are then adjusted for inter-industry differences.

Third, the definition of capital that we use includes all tangible assets in the business sector, equipment and structures, as well as land and inventories. The nominal value of land in the agriculture and non-farm business sectors is taken from the balance sheet for these sectors (Statistics Canada CANSIM Tables 002-0020 and 378-0004). The real value of land in those two sectors is taken from Hofmann, Filoso and Schofield (2005) who present an estimate of total area of the dependable agriculture land for cultivation and total area of urban land.

Data on the value of land at the industry level are scarce. In order to estimate the nominal value of land stock of individual industries, we multiply structure capital stock by land structure ratios.[12] The land structure ratios are derived from the corporate balance sheets which provide data on book values of land and structures by industry for the period 1972 to 1987 (CANSIM Table 180-0002).

12. Our methodology for estimating land is similar to the one used by the U.S. Bureau of Labor Statistics in its multifactor productivity estimates.

Figure 3
Share of nominal capital services by assets in the business sector, 1961 to 2002



Notes: ICT: information and communications technologies. M&E: machinery and equipment.
Source: Statistics Canada, Canadian Productivity Accounts.

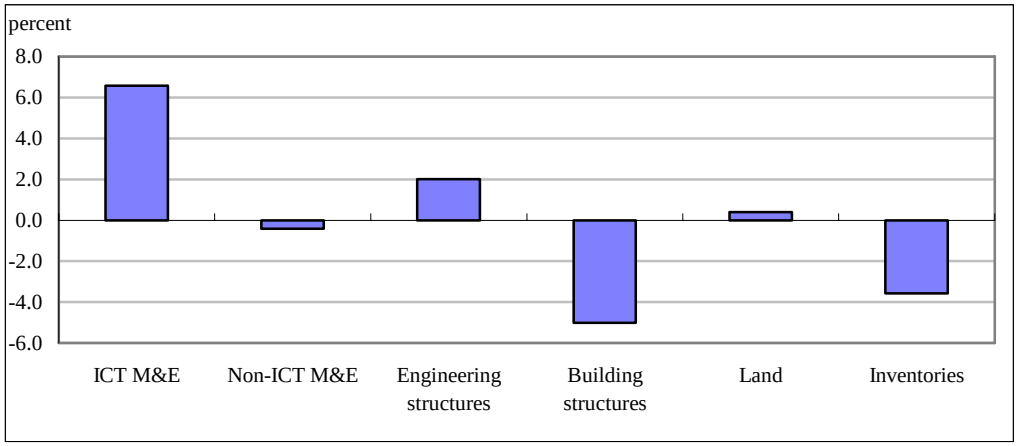
The real value of land at the industry level is estimated by deflating the nominal value of land using the structure capital's deflators.[13] The final estimates of land values at the industry level are benchmarked to the aggregate land stock in the total non-farm business sector.

Figure 3 tracks the share of nominal capital services by six major asset groups in the business sector for the period from 1961 to 2002. The six major asset groups are information and communications technologies machinery and equipment (ICT M&E),[14] non-ICT M&E, engineering structures, building structures, land, and inventories. Figure 4 shows the percentage point changes in the asset shares of aggregate capital services over that same period.

In 2002, the largest component of aggregate capital services was non-ICT M&E, followed by buildings structures and engineering structures. Non-ICT M&E accounted for 27.0% of aggregate capital services in 2002, building structure capital accounted for 24.3% of aggregate capital services, while engineering structure capital 18.3% of capital services. It should be noted that the latter two made up over 42.0% of the total—much more than the machinery and equipment component. Capital consists of a great deal more than machinery and equipment—and most of the capital that workers have to work with comes in forms other than machinery and equipment.

13. The structures deflator is used because it is felt to capture the component of land improvements that are most relevant to us.
14. The information and communications technologies machinery and equipment (ICT M&E) includes computers, software and telecommunication equipment.

Figure 4
Changes in the share of nominal capital services by assets in the business sector, 1961 to 2002



Notes: ICT: information and communications technologies. M&E: machinery and equipment.
Source: Statistics Canada, Canadian Productivity Accounts.

ICT M&E represents a relatively small share of capital services, accounting for 10.3% of capital services in 2002. But, the share of ICT M&E showed the largest increase in the 1961 to 2002 period. Over that period, the share of ICT M&E increased by 6.6 percentage points.

The engineering structure capital also increased its share of nominal capital services. Over the period from 1961 to 2002, the share of engineering structures rose from 16.3% to 18.3%—an increase of 2.0 percentage points. This was mainly the result of increases in petroleum and natural gas (see Baldwin and Dixon, 2007). However, the relative importance of the engineering capital in the aggregate capital services input declined over time as the engineering capital services increased at a slower rate than the total capital input (Table 2).

The share of non-ICT M&E remained virtually unchanged over time. The share of the remaining assets (building structures, land and inventories) declined for the period from 1961 to 2002. Inventory decline has been associated with the application of just-in-time production methods. The decline in buildings and engineering structures has been the result of long-term increases in capital productivity in those sectors that use this type of infrastructure investment—transportation, communications, utilities, and water (Baldwin and Dixon, 2007).

Table 2 summarizes the trend in growth of prices and quantities of capital services showing that the asset increasing its share the most was the one whose relative price was declining. There has been a long-term shift in capital services towards M&E and away from structure capital, land and inventories in the Canadian business sector. Of M&E capital, ICT increased the most. Over the period from 1961 to 2002, ICT capital increased at an annual rate of 14.1%. The dramatic increases in ICT capital services occurred as the price of ICT capital experienced a large decline. Canadian businesses have made large investments in ICT to take advantage of the dramatic decline in the price of ICT capital.

Table 2
Capital services growth by asset types in the business sector

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Quantity of capital services					
Total capital services	4.69	5.74	5.99	4.44	3.30
ICT[1] M&E[2]	14.12	7.60	17.24	20.58	13.74
Non-ICT M&E	4.24	5.97	6.35	3.70	2.09
Engineering structures	3.78	5.04	5.18	3.20	2.43
Building structures	4.45	6.61	5.63	4.21	2.09
Land	3.25	4.74	3.83	2.30	2.33
Inventories	2.64	4.41	4.50	0.69	1.65
Price of capital services					
Total capital services	3.56	3.65	7.93	3.31	1.66
ICT M&E	-3.26	3.75	-1.11	-7.07	-7.79
Non-ICT M&E	4.08	5.00	4.94	4.70	2.36
Engineering structures	4.86	5.05	14.06	1.72	2.85
Building structures	3.45	2.19	8.88	2.96	2.48
Land	5.22	1.65	13.53	3.11	6.30
Inventories	5.03	5.88	8.03	5.38	2.59

1. Information and communications technologies.
2. Machinery and equipment.
Source: Statistics Canada, Canadian Productivity Accounts.

The table also reveals a long-term decline in the growth in capital services in the Canadian business sector that we have documented previously (Baldwin et al., 2001, Chapter 6). Very rapid capital formation occurred in the 1960s and 1970s that is sometimes attributed to the introduction of new technologies that were postponed during the Great Depression and World War II. After 1979, the growth in investment and capital services declined, particularly after 1989 when annual capital growth was only 3.3% per year for the 1989 to 2002 period. This represents a sharp decline from the annual growth rate of 5.7% for the 1961-to-1973 period, and 6.0% for the 1973-to-1979 period. The slowdown in capital services growth after 1979 was pervasive across all assets except for ICT.

Table 3 and Figure 5 present the annual growth of capital services, capital stock and capital composition in the business sector. The capital services in the business sector increased at an annual rate of 4.7% over the period from 1961 to 2002. This is a result of a 3.2% increase in capital stock and a 1.5% increase in capital composition. The capital composition effect accounted for 31.0% of capital services growth over time. The changes in capital input towards machinery and equipment capital with short services life was a major source of capital services growth.

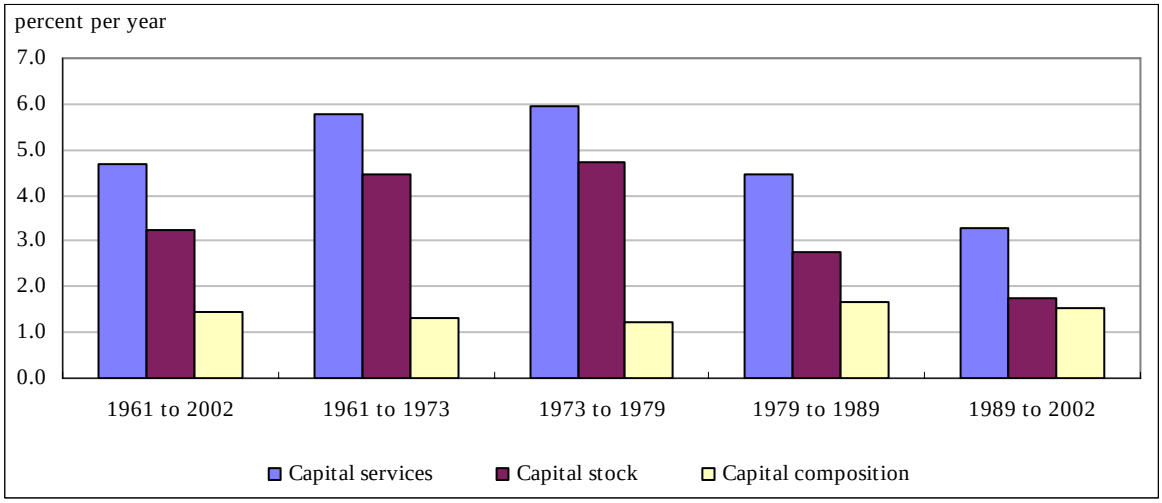
Table 3
Capital services, capital stock and capital composition growth in the business sector, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Capital services	4.69	5.74	5.99	4.44	3.30
Capital stock	3.23	4.47	4.72	2.77	1.75
Capital composition	1.46	1.27	1.28	1.67	1.55

Source: Statistics Canada, Canadian Productivity Accounts.

While capital stock growth declined over time, capital composition growth showed an increasing trend. The difference between capital services growth and capital stock growth becomes larger over time. In fact, almost half of the growth in capital services in the last period came from the quality-enhancing compositional change. Capital stock has become increasingly less accurate as a measure of capital services.

Figure 5
Annual growth of capital services, capital stock and capital composition in the business sector, selected periods, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

3.2.2 Labour services

This section presents the estimates of labour input in the Canadian business sector. Estimates of the growth in labour input are obtained by aggregating the growth in hours worked for different classes of workers, classified into 56 types by education, work experience and type (paid workers, self employed) with weights determined by their shares of labour compensation (see Gu et al. [2002] for the methodology and data sources for constructing labour input estimates in the Canadian Productivity Accounts).

(23) $\dot{L} = \dot{H} + \dot{Comp}$.

The difference between the growth in labour input $\dot{L}$ and hours worked $\dot{H}$ is the growth in labour composition $\dot{Comp}$ (also sometimes referred to as the growth in labour quality). This difference occurs when the highest-skilled workers (highest-paid) grow more rapidly than those with lower skills. The growth in labour quality reflects an increase in the skills of workers as measured by their education attainment and work experience.

Since 1961, the composition of the labour force has changed dramatically (Gu et al. [2002]). From 1961 to 1979, the share of younger workers (less than 25 years) first increased dramatically and then fell continuously until the mid-1990s. As this group of post-war boomers aged, workers in the age group from 25 to 44 years increased from the 1970s to the early 1990s and then declined. This long demographic cycle led first to a decline in the average experience of the workforce and more recently to an increase.

There have also been dramatic changes in the educational qualifications of the labour force. The percentage with only high school has fallen steadily while those with post-secondary degrees has increased. For example, those with some post-secondary education increased from less than 10% in 1961 to over 40% by 2000.

These changes have led to changes in the composition of workers. Additions of relatively large portions of younger workers in the period at first led to a declining average age. Later, additions of middle-aged workers led to an increase in the average experience level. These two changes have led to quite opposite effects on the contribution to labour inputs that came from upgraded skills—what is termed in this paper, labour composition. The effect of the changing level of experience occasioned by first, a greening of the labour force and then, its aging follows an inverted U—with first a decline coming from the experience component, then an increase.

But the impact of changing experience in most periods is small. Far more important is the increase in the skill component that comes from increases in education levels. And since upgrading of education levels is more or less continuous during the period, this force provided most of the increase caught by the labour composition or quality component of labour input growth.

Table 4 summarizes the trend in growth of prices and quantities of labour input by education. There has been a long-term shift in hours worked toward workers with university degrees or above. For the period 1961 to 2002, the growth in labour input of university-educated workers was more than twice that of the non-university-educated workers. The labour input of university-educated workers increased at an annual rate of 5.5% over that period, while the labour input of non-university-educated workers increased at 2.0% per year.

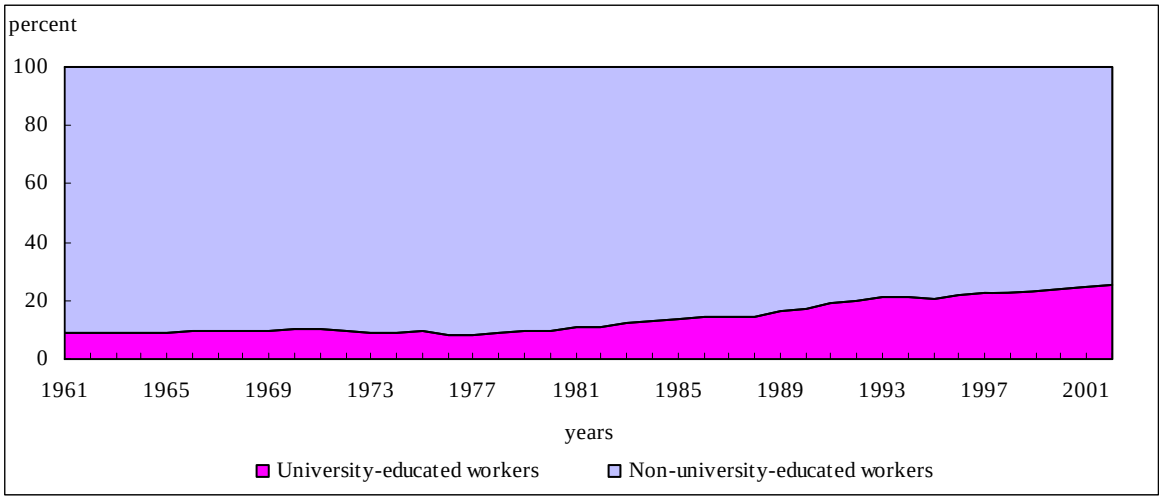
Table 4
Labour input growth by education in the business sector, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Quantity of labour input					
Total labour input	2.44	3.01	2.34	2.55	1.88
University-educated workers	5.48	5.01	6.20	6.25	4.99
Non-university-educated workers	2.02	2.84	2.03	2.12	1.19
Prices of labour input					
Total labour input	5.38	5.94	10.29	5.87	2.23
University-educated workers	5.23	4.10	7.85	7.82	3.08
Non-university-educated workers	5.33	6.10	10.48	5.62	2.03

Source: Statistics Canada, Canadian Productivity Accounts.

Figure 6 shows that the share of labour income going to the university-educated workers showed little change before the mid-1970s. But it increased dramatically after the mid-1970s. From 1977 to 2002, the share of university-educated workers in labour income increased from 7.0% to 23.3%.

Figure 6
Share of nominal labour income by education in the business sector, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

Table 5 and Figure 7 present the growth of labour services, hours worked and labour composition in the business sector. The growth of labour services was highest in the 1961-to-1973 and 1979-to-1989 periods. The growth of labour services was lowest in the most recent period from 1989 to 2002. Over the 1961 to 2002 period, labour services rose at an annual rate of 2.5%. Over time, there has been less variation in the growth in hours worked. Indeed, the growth in hours worked is relatively similar during the first three decades—around 2.0%. But this is almost halved in the 1990s to around only 1.2% as population growth slowed and labour force participation rates did the same.

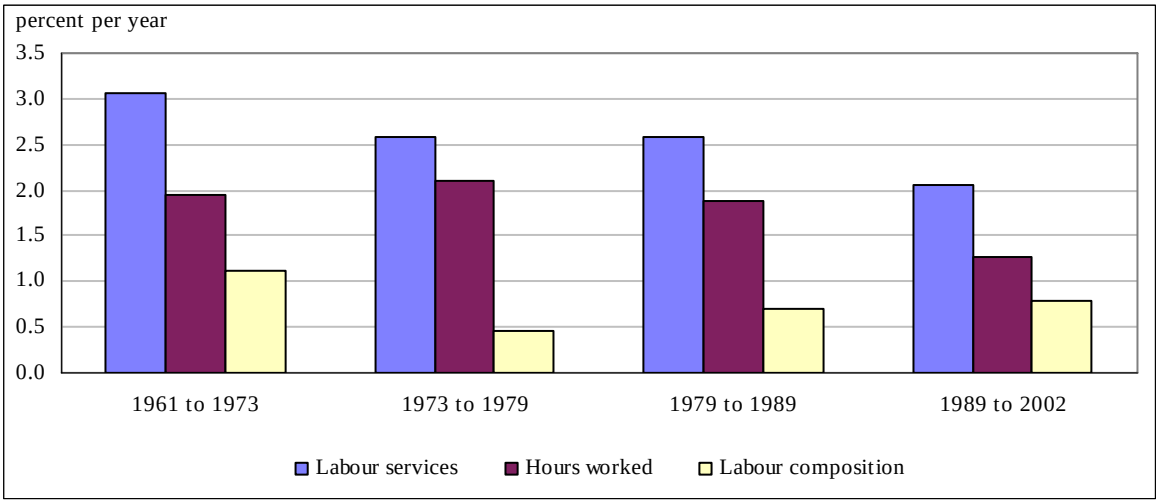
Table 5
Labour services, hours worked and labour composition growth in the business sector, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Labour services	2.44	3.01	2.34	2.55	1.88
Hours worked	1.71	1.97	1.96	1.92	1.20
Labour composition	0.73	1.04	0.38	0.64	0.68

Source: Statistics Canada, Canadian Productivity Accounts.

But there has been considerable variation in the growth in total labour input that comes from changes in the skill level of the workforce. Over the period from 1961 to 2002, the growth of labour composition due to the increase in the skills of workers was 0.7% per year in the business sector. It accounted for 30.0% of labour input growth for the period from 1961 to 2002. The largest contributions were made in the first and last periods. This increase in worker skills was an important source of labour productivity growth in the business sector.

Figure 7
Annual growth of labour input in the business sector, selected periods, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

The growth of labour composition was the slowest in the 1973-to-1979 period as the baby-boom generation was entering the workforce and the declining experience level somewhat offset the increasing educational attainments of these new workers. The most rapid gains occurred in the 1961-to-1973 period and in the 1989-to-2003 period. After 1979, labour composition growth more than doubled as the average education and experience of the workers both increased. The growing importance of the knowledge economy is evidenced by the increasing share of labour input that is attributed to the quality component of the growth in labour services.

It is also significant that in the periods when skills (labour composition) grew the most that multifactor productivity did likewise. While the growth accounting framework makes use of a decomposition that assumes technological progress is separate from factor accumulation, there is evidence that this assumption may be an oversimplification. Gu and Wang (2004), for instance, find that multifactor productivity growth at the industry level is highest for those industries that have larger shares of highly educated workers—thereby suggesting a feedback from skills to technological change. Other work by Baldwin and Gellatly (2004) using micro data shows that those firms that are most innovative are most likely to provide skills training to their workers.

3.2.3 Sources of output growth

As we have shown (Equation [7]), real gross domestic product (GDP) growth can be decomposed into three sources: the percentage of growth arising from the growth in capital input, the growth in labour input and multifactor productivity growth.

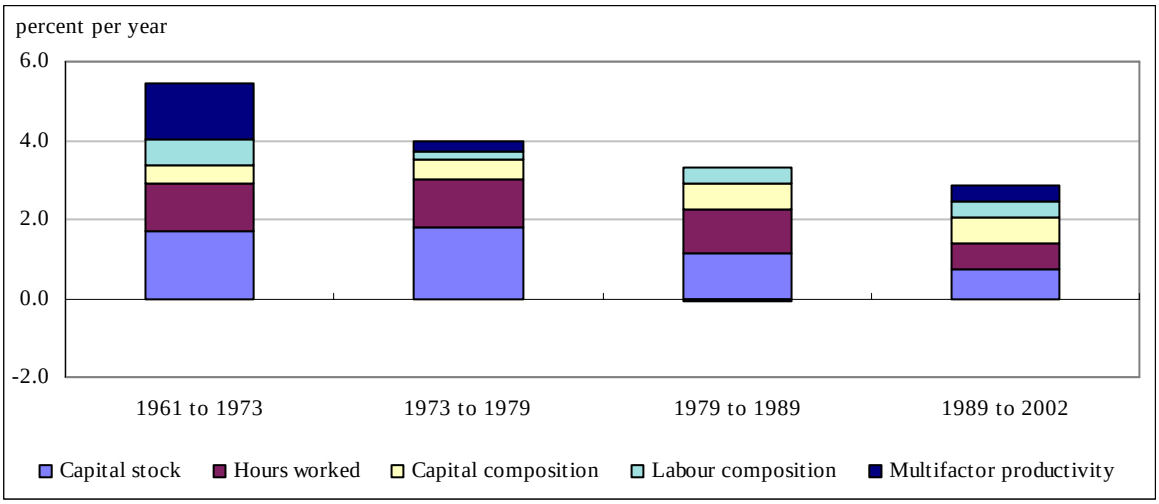
This section examines the sources of output growth in the business sector. In Table 6 and Figure 8, output growth is decomposed into the growth that came from more labour inputs, the growth that came from more capital inputs and the residual growth that came from productivity improvements. The contribution made by labour and capital is just the rate of growth of each of these inputs weighted by their respective shares of income.

Table 6
Sources of output growth in the business sector, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Output	3.87	5.46	3.96	3.22	2.86
Contribution of capital services	1.83	2.16	2.31	1.80	1.33
Capital stock	1.26	1.68	1.82	1.12	0.71
Capital composition	0.58	0.48	0.49	0.68	0.62
Contribution of capital by asset types					
ICT[1] M&E[2]	0.38	0.12	0.31	0.55	0.54
Non-ICT M&E	0.45	0.63	0.64	0.40	0.23
Engineering structures	0.27	0.29	0.39	0.30	0.18
Building structures	0.47	0.70	0.60	0.41	0.23
Land	0.10	0.14	0.10	0.08	0.08
Inventories	0.16	0.27	0.28	0.05	0.08
Contribution of labour services	1.47	1.87	1.43	1.50	1.11
Hours worked	1.03	1.22	1.19	1.12	0.69
Labour composition	0.45	0.65	0.23	0.38	0.41
Multifactor productivity	0.56	1.44	0.22	-0.09	0.42

1. Information and communications technologies.
2. Machinery and equipment.
Source: Statistics Canada, Canadian Productivity Accounts.

Figure 8
Sources of output growth in the business sector, selected periods, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

For the period from 1961 to 2002, output grew 3.9% per year in the business sector. Capital services contributed 1.8 percentage points or 47.3% of the business sector output growth. Labour input contributed 1.5 percentage points or 38.1% of the output growth. Multifactor productivity growth was the least important source of output growth in the business sector and contributed 0.6 percentage points or 14.6% of the output growth.

It is noteworthy that a good portion of the growth in both labour and capital came from changes in the composition of each aggregate—that is, the composition of the inputs changed from less productive to more productive inputs over the period. The growth that is due to upgrading accounted for about one-third of total growth for both labour and capital. The share of total labour input growth is relatively constant during the period. But the share of total capital services growth coming from a shift of capital to those assets with higher marginal productivity increased over time from 22.1% in the 1961-to-1973 period to 46.8% in the 1989-to-2002 period. Capital growth therefore declined over time—but the quality of the capital stock, at least as measured by the compensation effect, continued to increase over time.

For those who wish to compare these estimates to those of other countries, it should be remembered that the Canadian Productivity Accounts calculate their labour and capital inputs with 'quality' components included. That is, the Accounts do not just sum hours worked or sum capital employed. The Accounts weight hours worked in 56 different categories of work and 28 asset types by estimates of relative marginal productivity (using factor input prices). This process yields substantially higher estimates of the growth in factor inputs (labour and capital) and concomitantly lower estimates of multifactor productivity. For example, the labour composition effect averaged 0.7% annually per year from 1961 to 2002. This translates into an average of about 0.5% annually when multiplied by the share of labour. The same capital composition effect averaged around 1.5% per year which is about 0.6% per year when multiplied by capitals' share. If these two were added back into the multifactor productivity estimate of 0.6% annually, the multifactor productivity estimate would increase to 1.6% per year and average 41.0% not 14.6% of the annual growth rate in real output during this period. It is clearly important then to take into

account the heterogeneity of factor inputs—for it changes the conclusions that can be drawn from the growth accounting framework. We conclude that most of the growth in output came from increased factor inputs—not from disembodied technological progress. If we had not corrected for the changing quality of factor inputs, we would have drawn the opposite conclusion.

The contribution of capital services to output growth can be divided into contributions from six major assets: ICT M&E, non-ICT M&E, building structures, engineering structures, land, and inventories. Over the period 1961 to 2002, the largest contribution to output growth came from building structures and non-ICT M&E, followed by ICT M&E and engineering structures. Land and inventories made a small contribution to output growth. For the period from 1961 to 2002, building structure capital contributed 0.5 percentage points to business sector output growth, non-ICT M&E 0.5 percentage points, ICT M&E 0.4 percentage points, and engineering structure capital 0.3 percentage points.

Output growth trended downward over time in the business sector up to 1990 and then moved back up after that. Real GDP growth was strongest in the 1961-to-1973 period when real GDP rose at an annual rate of 5.5%. After 1973, real GDP growth declined. It rose at an annual rate of 4.0% in the 1973-to-1979 period. Real GDP growth was quite similar in the 1980s and 1990s. It increased at 3.2% in the 1979 to 1989 period and 2.9% in the 1989-to-2002 period.

The decline in output growth between the 1961-to-1973 and 1973-to-1979 periods reflects the decline in labour service and MFP growth between those two periods. Capital service growth actually increased in the 1973-to-1979 period.

The second decline in output growth—between the 1973-to-1979 and 1979-to-1989 periods—can be attributed to declines in capital service growth and MFP growth. Labour service growth increased between those two periods.

Output growth did not show further decline after 1989. It began to increase after 1991 (Figure 1b). The similar growth rates of output between 1979-to-1989 and 1989-to-2002 periods reflect the net effect of two offsetting factors: slower growth of capital and labour inputs and faster MFP growth in the 1989-to-2002 period.

The contributions of labour and capital are much more stable than multifactor productivity. Multifactor productivity growth is the highest in the 1961-to-1973 period. It is lowest in the 1979-to-1989 period. The growth in capital services, though in decline, was generally more important than the growth in labour services. Together the growth rates in these two factor inputs have contributed over 1.0 percentage points of the 2.3 percentage points decline in output between the periods from 1961 to 1973 and 1973 to 2002. The rest of the decline comes from a much lower growth in multifactor productivity. However, between the 1980s and 1990s, while the growth in labour and capital inputs declined, multifactor productivity increased enough to substantially offset these declines.

The evidence on the contribution to output growth by assets shows how capital structure has changed over time in the Canadian business sector. The contribution of information and

communication technologies has increased steadily throughout the period from 1961 to 2002. The share of the contribution that engineering structures made to output growth increased in the 1973-to-1979 and 1979-to-1989 periods, and then declined somewhat in the 1989-to-2002 period. The share of the contribution of all other assets to output growth declined over time.

ICT investment is commonly associated with new economy industries while engineering capital investment is associated with (old economy) natural resource industries. The evidence on the contributions of ICT and engineering structure capital to output growth suggests that both new and old economy industries are an important part of the Canadian business sector. The old resource and resource-based economy showed little sign of decline in Canada.

Many factors influence the rate of growth in labour inputs—changing social patterns that lead to higher labour force participation by women, increases in participation by older males, and immigration. It is, nevertheless, the case that over the period studied, the employment growth rate has decreased slowly. These declines do not necessarily mean that overall growth must fall since the contribution made by capital growth has been larger than that of labour over the period. Nevertheless, the historical record here has seen the contribution made by the growth in capital also fall over the period—by even more than the contribution of labour growth—starting in the 1980s and continuing into the 1990s. The residual, unmeasured category (multifactor productivity growth) has also declined since its high point in the 1961-to-1973 period—though there is evidence this decline reached its low at the end of the 1980s and that MFP has begun to move back up.

3.2.4 Sources of labour productivity growth

An alternate decomposition (Equation [15] or its extension in Equation [22]) allows us to track the sources behind labour productivity growth.

Labour productivity is measured as output per hour, whereas multifactor productivity is defined as output per unit of combined capital and labour inputs (Equation [10]). Labour productivity measures do not explicitly account for the effects of capital or of changes in the composition of labour on output growth. But it is a measure that receives as much or more attention than the more comprehensive multifactor productivity growth statistic—because it closely tracks long-run changes in real wages. It is also linked to output growth by a simple identity:

$$\dot{Q} = \dot{LP} + \dot{H} \quad (24)$$

That is, the sum of labour productivity growth and hours growth is equal to output growth. Over the 1961-to-1973 and 1989-to-2002 periods, labour productivity growth predominated in output growth, as shown in Table 7. In the 1973-to-1979 period, labour productivity growth and hours growth made a similar contribution to output growth, while in the 1979-to-1989 period, labour productivity growth was a less important contributor to output growth. This reflects the rapid employment growth in the late 1970s and 1980s as the baby-boom generation entered the workforce.

Table 7
Sources of labour productivity growth in the business sector, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Output	3.87	5.46	3.96	3.22	2.86
Hours worked	1.71	1.97	1.96	1.92	1.20
Labour productivity	**2.16**	**3.50**	**2.00**	**1.30**	**1.66**
Contribution to labour productivity growth from:					
Capital deepening	1.15	1.41	1.55	1.01	0.83
ICT[1] M&E[2]	0.34	0.09	0.27	0.49	0.49
Non-ICT M&E	0.26	0.42	0.44	0.20	0.09
Engineering	0.15	0.18	0.23	0.13	0.09
Building	0.29	0.49	0.39	0.23	0.10
Land	0.04	0.08	0.05	0.01	0.04
Inventories	0.06	0.15	0.17	-0.05	0.02
Labour composition	0.45	0.65	0.23	0.38	0.41
Multifactor productivity growth	0.56	1.44	0.22	-0.09	0.42

1. Information and communications technologies.
2. Machinery and equipment.
Source: Statistics Canada, Canadian Productivity Accounts.

As outlined previously, growth in labour productivity is determined by the growth in multifactor productivity as well as changes in capital intensity (the amount of capital per hour worked) and labour composition (percentage of the growth that comes from growth in skilled workers) (Equation [22]).

Labour productivity in the business sector has generally increased at a faster rate than multifactor productivity. Since 1961, labour productivity has grown at an annual rate of 2.2%. This compares with an annual rate of 0.6% for multifactor productivity.

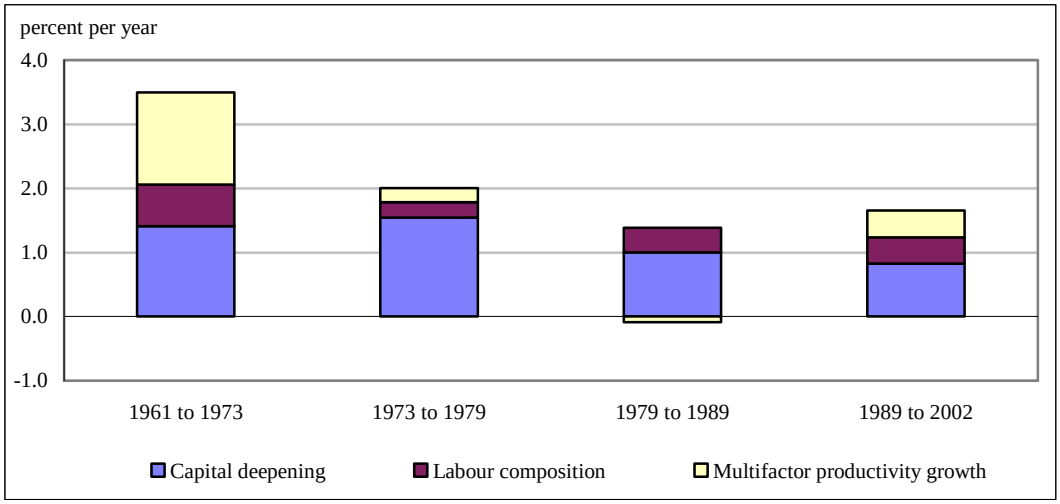
The difference between these two measures of productivity comes either from an increase in the capital-to-labour ratio or a growth in the skills of workers, as measured by increases in the educational attainment and work experience of the workforce.

Table 7 and Figure 9 include a decomposition of productivity growth into contributions from capital deepening, changes in labour composition, and multifactor productivity growth.

For the 1961-to-2002 period, labour productivity grew at annual rate of 2.2% in the business sector. Capital deepening was the most important factor. It contributed 1.2 percentage points and 53.2% of the labour productivity growth.

The change in labour composition was an important source of labour productivity growth in the business sector for the 1961-to-2002 period, contributing 0.5 percentage points or a quarter of labour productivity growth in the business sector. A positive labour composition effect captures the increase in the average educational attainment and experience levels of workers. Investments in education and training have made a significant contribution to labour productivity growth in Canada.

Figure 9
Sources of labour productivity growth in the business sector, selected periods, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

Over the last four decades, investment in physical and human capital together accounted for more than three-quarters of labour productivity growth in the business sector. The key to rising productivity growth has been investment—both in machines and in education of workers.

Multifactor productivity growth contributed the remaining 0.6 percentage points or 26.1% of labour productivity growth. MFP growth is often associated with technological change, organizational change, scale economies or changes in utilization rates.[15] While contributing substantially to labour productivity growth, its importance is nevertheless, in this framework, only third behind investment in general.

After strong labour productivity growth in the 1960s and early 1970s, productivity growth slowed markedly through the 1980s, with a decline in labour productivity growth from 3.5% to 2.0% between 1961 to 1973 and 1973 to 1979, and a decline from 2.0% to 1.3% between 1973 to 1979 and 1979 to 1989.

After 1989, labour productivity growth showed a marked acceleration. It rose at an annual rate of 1.7% over the 1989-to-2002 period, which represented a 0.4-percentage-points increase from the 1979-to-1989 period.

The decline in labour productivity growth between 1961 to 1973 and 1973 to 1979 can be attributed to the decline in MFP growth and lower growth in the labour composition effect. The contribution of capital deepening increased between these two periods and thus contributed to an increase in labour productivity growth.

15. The studies on the determinants of productivity growth suggest that there is complementarity between physical capital, human capital and technical process (OECD, 1991; Gera, Gu and Lee, 1998). The growth accounting framework for examining the sources of labour productivity growth does not allow for this complementarity.

The second decline in labour productivity growth between 1973 to 1979 and 1979 to 1989 reflects the decline in capital deepening and the decline in multifactor productivity (MFP) growth. The contribution of labour compositional changes increased and made a positive contribution to labour productivity growth.

The recent pickup in labour productivity growth after 1989 is due to a pickup in MFP growth in that period. Gu and Wang (2004) find that the strong MFP growth is related to ICT investment and rapid technological changes across Canadian industries, a finding similar to Stiroh (2002) for U.S. industries.

The increased education level and experience of workers also made a positive contribution to the labour productivity growth acceleration. The productivity contribution of capital deepening was virtually unchanged between the 1979-to-1989 and 1989-to-2002 periods. Capital deepening was not a factor in the post-1989 productivity growth acceleration.[16]

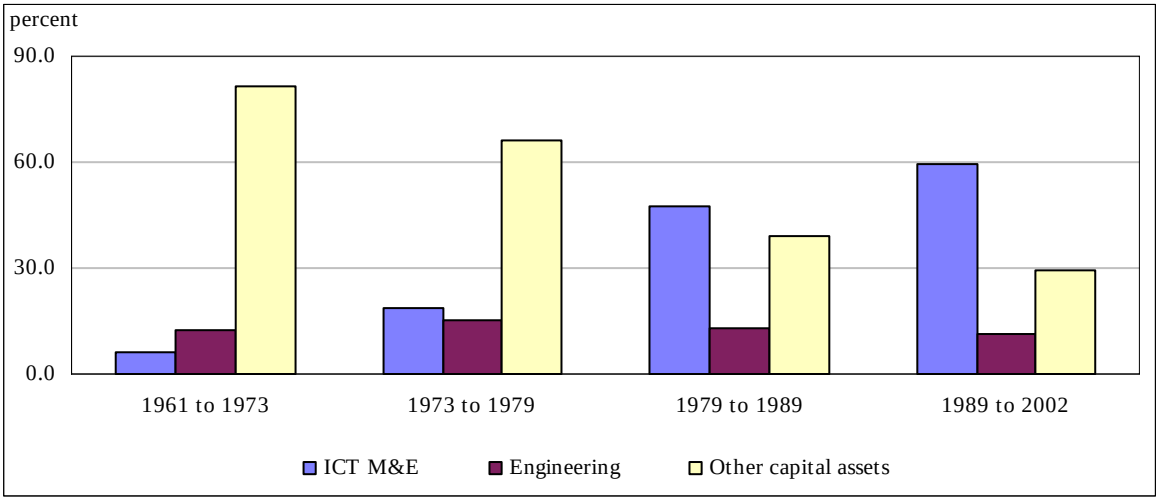
In two of the periods, capital deepening and multifactor productivity have moved together. From 1961 to 1973, the contribution from both was high. In 1979 to 1989, both declined relative to earlier periods. This suggests that there are particular time periods when it is technology that is being driven by investment in the type of traditional assets that are measured in capital stock. In other periods (1973 to 1979), capital deepening is high but multifactor productivity was nevertheless lower, thereby suggesting that traditional investments are not sufficient conditions for technological progress—that there may have been deficiencies in this period in the complementary expenditures that are required for change.

Figure 10 plots the percentage share of assets in the contribution of capital services to labour productivity growth. The contribution of ICT capital deepening increased over time. In the 1961-to-1973 period, little of capital's contribution to labour productivity was from ICT investment. In the 1989-to-2002 period, 58.6% of the productivity contribution of capital services can be attributed to ICT capital deepening. Moreover, it is significant that it is during the latter period that multifactor productivity growth has once more picked up. This has been used by some to suggest that it is not so much increases in capital intensity as the type of capital that matters.

The contribution of engineering capital deepening showed little change over time. Engineering capital and associated natural resource industries remained an important source of labour productivity growth in Canada. Despite the intense interest in the new or high-tech economy built around information and communications technologies, Canada still focuses heavily on the resource sector and has large investments in the infrastructure industries—electricity, communications, and transport and pipelines.

16. This stands in a contrast to the sources in productivity growth acceleration after the mid-1990s in the United States (Jorgenson, Ho and Stiroh, 2005). In the United States, the labour productivity growth acceleration is due to both capital deepening and faster MFP growth. The capital deepening effect is a more important contributor to faster labour productivity growth than increased MFP growth.

Figure 10
Share of capital contribution to aggregate labour productivity growth by assets, selected periods, 1961 to 2002



Notes: ICT: information and communications technologies. M&E: machinery and equipment.
Source: Statistics Canada, Canadian Productivity Accounts.

The contribution of other capital assets (in particular, non-ICT machinery and equipment) to labour productivity growth declined over time. In the 1960s and the 1970s, those assets were an important source of labour productivity growth. After 1989, the contribution of those assets to labour productivity growth was small.

4. Output growth and labour productivity growth at the industry level

Productivity growth for the business sector as a whole depends on the rates of productivity growth in the underlying industries that make up the economy. The rate of technological change is not the same in all industries. New technologies affect industries differently.

This section examines the sources of output growth and labour productivity growth at the industry level. As there is a continued interest in the role that new economy industries and natural resource industries (so-called old economy industries) play in Canadian economic growth, we will compare the performance of new economy and natural resource industries.

Examination of trends at the industry level allow the analyst to ascertain whether changes at the economy level are widespread or concentrated only in some industries. It allows us to evaluate whether there is substantial heterogeneity across industries.

A note of caution is however required. As the statistician drills down from the level of the total economy, data become less suited for analysis. Disaggregated data that contain errors can be aggregated into reasonable national totals because errors in individual series offset one another. Thus aggregate numbers that are constructed from disaggregated data may be suitable for understanding national trends, when the individual series are not suitable for understanding

trends in individual industries. For example, if the price growth of an output is understated, the growth of output in the industry will be overstated, but the growth of inputs into other industries that use that input will be understated. Productivity estimates will be too high in the former and too low in the latter—but the two errors offset one another at the level of the total economy.

There is a temptation not to publish data that seems to suggest data problems. Some have argued that negative productivity growth is not reasonable and therefore, some agencies suppress the results in these cases. According to this reasoning, the industries with negative productivity growth should be suppressed. But analysis such as this paper is aimed at improving the quality of data. It is only by presenting what the underlying series look like that we can hope to inform debate on whether problems exist and whether they should be corrected. Negative productivity trends may be quite legitimate. We therefore present the entire spectrum of industry results here in order to enhance informed discussion.

4.1 Trends in output and productivity growth at the industry level

While the appropriate output concept is value-added for the aggregate business sector, the output concept at the industry level can be value-added, gross output, or sectoral output. Statistical agencies tend to use different output measures to measure productivity at the industry level (Schreyer, 2001; Dean and Harper, 2001; and Baldwin et al., 2001, Appendix 1).

Statistics Canada uses the value-added output concept to measure industry-level labour productivity. To measure MFP at the industry level, Statistics Canada uses all output measures and publishes three MFP measures (Durand, 1996; Baldwin et al., 2001, Appendix 1). In contrast, the U.S. Bureau of Labor Statistics (BLS) uses sectoral output to measure labour and multi-factor productivity at the industry level (Dean and Harper, 2001).

The difference between value-added and gross output is purchased intermediate inputs. The real value-added growth is related to real gross output growth via the following "double deflation" formula:

$$(25) \qquad \dot{Q} = \bar{w}\dot{A} + (1-\bar{w})\dot{U} ,$$

where Q denotes real gross output, A is real value-added, and U is real intermediate inputs, $\bar{w}$ is the two-period average share of nominal value-added in nominal gross output, the dot is the log difference between two periods.

The difference between gross-output growth and value-added growth depends on changes in the use of intermediate inputs in the production process. When industries increase the share of purchased intermediate inputs in production, gross output growth will exceed value-added growth.

The difference in gross output and sectoral output is intra industry transactions, which represent the deliveries of intermediate inputs within domestic industries. Sectoral output is calculated as gross output net of those transactions. The Bureau of Labor Statistics argues that sectoral output has an advantage over gross output as sectoral output is not sensitive to the degree of vertical integration within industries (Bureau of Labor Statistics [BLS], 1997).

However, to estimate sectoral output, intra-industry transactions have to be estimated. This imposes a strong assumption that the share of imports in goods and services used for intermediate inputs is equal to the share of imports in goods and services purchased for final demand (consumption and investment).

Table 8 presents the growth rates of output based on value-added, sectoral output and gross output for 13 industries of the business sector for 1961 to 2002. All three output measures show that output has grown faster in the service sector than in the goods sector. This reflects a long-term shift of output and employment towards the service sector in Canada.

Table 8
Output growth by industry, 1961 to 2002

	Value-added	Sectoral output	Gross output
	percent per year		
Professional, scientific and technical services	5.99	6.73	6.77
Information and cultural Industries	6.45	6.42	6.42
Wholesale trade	5.36	5.36	5.37
Education and health care services	4.89	5.06	5.07
Utilities	4.47	4.67	4.63
Finance, insurance, real estate, and renting and leasing	4.19	4.48	4.57
Retail trade	4.53	4.54	4.54
Other services (except public administration)	3.31	3.89	3.92
Transportation and warehousing	3.90	3.63	3.74
Manufacturing	3.75	3.87	3.72
Mining and oil and gas extraction	2.81	3.31	3.44
Agriculture, forestry, fishing and hunting	1.42	2.52	2.80
Construction	2.54	2.59	2.59
Industry median	4.19	4.48	4.54

Note: Industries are ranked based on the growth of gross output.
Source: Statistics Canada, Canadian Productivity Accounts.

The three fastest growing industries are all service-producing industries: professional, scientific and technical services; information and cultural industries; and education and health care services. All three slowest growing industries are goods-producing industries: construction; agriculture, forestry, fishing and hunting; and mining and oil and gas extraction.

Gross output grew faster than value-added in almost all industries except in transportation and warehousing industries and in information and cultural industries. Most industries have increased the share of purchased intermediate inputs in production over time.

The relationship between gross output and sectoral output does not suggest any large change in the importance of intra industry transactions. But the difference between gross output and value-added suggests that inter-industry purchases have become relatively more important. This would have occurred if diversification across industries had declined and plants had begun to source more of their inputs out to other firms. Baldwin, Beckstead and Caves (2002) suggest this has occurred.

Gross output grew at a faster or similar rate than sectoral output in almost all industries except in manufacturing and wholesale industries. In those two industries, an increasing share of intermediate inputs is purchased from other industries and abroad.[17] As a result, gross output growth was slower than sectoral output growth in the manufacturing and wholesale trade industries.

Table 9 presents labour productivity growth by industry over the 1961-to-2002 period. It ranks the industries by labour productivity growth based on gross output. A number of findings emerge from the table. First, the goods-producing sectors tend to have faster labour productivity growth than the services-producing sectors. This is in contrast to trends in output growth. Here the services sectors have faster output growth than goods sectors.

Table 9
Labour productivity growth by industry, 1961 to 2002

	Value-added	Sectoral output	Gross output
	percent per year		
Agriculture, forestry, fishing and hunting	3.24	4.34	4.62
Information and cultural Industries	3.78	3.74	3.75
Manufacturing	3.05	3.18	3.03
Utilities	2.52	2.72	2.67
Wholesale trade	2.60	2.60	2.60
Retail trade	2.58	2.59	2.59
Transportation and warehousing	2.48	2.22	2.33
Mining and oil and gas extraction	1.25	1.75	1.88
Professional, scientific and technical services	0.80	1.55	1.58
Finance, insurance, real estate, and renting and leasing	1.06	1.34	1.44
Construction	1.24	1.30	1.30
Other services (except public administration)	0.44	1.01	1.04
Education and health care services	0.10	0.27	0.27
Industry median	2.48	2.22	2.33

Note: Industries are ranked based on the growth of labour productivity defined as gross output per hour worked.
Source: Statistics Canada, Canadian Productivity Accounts.

Second, the industries with the highest labour productivity growth include the industries with slowest output growth: agriculture, forestry, fishing and hunting; manufacturing; and transportation and warehousing. There are industries here both in the goods and services side, so that average productivity differences between sectors should not be construed to imply that all service sectors are laggards. It should also be noted that there is a negative correlation between output growth and labour productivity growth across industries. However, the correlation is not statistically significant. Nevertheless, it suggests that output growth in not a necessary condition for productivity growth.

17. The evidence on manufacturing sector reflects the trend towards outsourcing of goods and services in that sector.

Third, the top five industries with the fastest labour productivity growth are: agriculture; information and cultural industries; manufacturing; utilities; and wholesale trade. This top-five list includes new economy industries (such as information and cultural industries) as well as (old economy) natural resource industries (such as agriculture, forestry, fishing and hunting; and utilities). Once again, this suggests that it is difficult to use generalities to describe which industries will experience the most amount of technological change. This suggests that technological advances are not easy to predict or to classify. They occur at different times in different places.

Almost the same picture emerges when we compare multifactor productivity growth between industries (Table 10). Once again, agriculture, information and cultural industries, manufacturing, utilities, and wholesale trade are among the leaders. There is a positive and statistically significant correlation between labour productivity growth and multifactor productivity growth across industries.

Table 10
Multifactor productivity growth by industry, 1961 to 2002

	Value-added	Sectoral output	Gross output
	percent per year		
Information and cultural Industries	2.02	1.52	1.45
Wholesale trade	1.81	1.22	1.21
Retail trade	1.64	1.10	1.10
Utilities	1.27	1.04	1.03
Transportation and warehousing	1.50	1.01	0.92
Agriculture, forestry, fishing and hunting	1.59	0.96	0.86
Manufacturing	1.81	0.80	0.61
Construction	0.48	0.22	0.22
Education and health care services	-0.07	-0.03	-0.03
Finance, insurance, real estate, and renting and leasing	-1.18	-0.91	-0.81
Mining and oil and gas extraction	-1.38	-1.08	-1.04
Other services (except public administration)	-2.17	-1.40	-1.35
Professional, scientific and technical services	-2.48	-1.93	-1.85
Industry median	1.27	0.80	0.61

Note: Industries are ranked based on the growth of multifactor productivity based on growth output.
Source: Statistics Canada, Canadian Productivity Accounts.

Four service industries (education and health care; finance, insurance, real estate, and rental and leasing; professional, scientific and technical services; and other services) and mining and oil and gas extraction industries had negative MFP growth over the 1961-to-2002 period. Negative multifactor productivity (MFP) growth rates are also reported for these U.S. industries (Jorgenson, Ho and Stiroh, 2005). Studies in the United States suggest two possible explanations: failure to account for quality changes in output in those industries or deteriorating productive efficiency due to such factors as rising barriers to entry and government regulations.

The negative growth in some industries may be the result of imperfections in methodology or in data. In the finance sector, economists are still debating the nature of output that should be included in the Canadian Productivity Accounts. In the area of mining, the Accounts fails to take into account the real output that results from new discoveries and therefore, may underestimate growth in exploration output.

Much has been made of the impact of productivity increases in the agriculture sector. Over this century, these increases have allowed an urban society to develop. The large increases in agricultural productivity have meant that a large urban workforce could be supported by a smaller and smaller farm population. The productivity increases of the pre-World War II period have continued into the present. During the last four decades, the agriculture sector has continued to lead in terms of productivity gains.

Transportation systems have also produced very high productivity gains. New generations of jet aircraft have allowed airlines to increase productivity; transportation deregulation has influenced productivity in the rail industry, as have new diesel systems.

At the same time, the communications industries have experienced dramatic growth in productivity. As new technologies have been introduced, the cost of telephone messages has fallen. During the last four decades, the information and communication sector has the highest MFP growth and the second-highest labour productivity growth.

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

Despite these gains in the service sectors, manufacturing has continued its strong productivity performance. In this sector, new computer-based technologies in design and engineering, in fabrication and assembly, in communications and in integrated control processes have been introduced and have improved productivity. Studies using establishment-level data have consistently shown that plants introducing these new technologies have had the fastest productivity growth (Baldwin and Sabourin, 2002).

4.2 Sources of output and productivity growth at the industry level

In this section, we use growth accounting techniques to examine the sources of output growth and productivity growth at the industry level. There are three output concepts we can choose for industry-level productivity analysis: value-added, sectoral output, and gross output. For this paper, we will choose the gross output concept of production, as this approach allows us to consider the complete production process of firms and industries by examining not only the role of labour and capital services but also the role of intermediate inputs such as semiconductors, services outsourcing and offshoring in productivity growth (Jorgenson, Ho and Stiroh, 2005).

The sectoral output approach is similar to the gross output approach. However, to estimate sectoral output, we must impose a strong assumption that the share of imports in goods and

services used for intermediate inputs is the same as the share of imports in goods and services purchased for final demand.

The growth of gross output can be decomposed into the contribution of capital, labour, intermediate inputs and multifactor productivity (MFP) growth. The contribution of an input is defined as the product of the nominal output share of the input and the growth of the input.

Table 11 presents the decomposition results of output growth for the 13 industries of the business sector over the period from 1961 to 2002. The relative importance of capital, labour, intermediate inputs, and MFP growth in output growth varies across industries. The economy is made up of industries that range from highly capital intensive to more labour intensive.

Table 11
Sources of output growth by industry, 1961 to 2002

	Gross output	Capital	Labour	Intermediate inputs	Multifactor productivity
	percent per year				
Agriculture, forestry, fishing and hunting	2.80	0.28	-0.34	2.01	0.86
Mining and oil and gas extraction	3.44	2.70	0.33	1.45	-1.04
Utilities	4.63	2.08	0.53	0.98	1.03
Construction	2.59	0.26	0.56	1.55	0.22
Manufacturing	3.72	0.37	0.29	2.44	0.61
Wholesale trade	5.37	0.83	1.55	1.77	1.21
Retail trade	4.54	0.67	1.29	1.47	1.10
Transportation and warehousing	3.74	0.65	0.72	1.46	0.92
Information and cultural industries	6.42	2.00	1.03	1.93	1.45
Finance, insurance, real estate, and rental and leasing	4.57	2.54	1.01	1.83	-0.81
Professional, scientific and technical services	6.77	3.02	3.14	2.46	-1.85
Other services (except public administration)	3.92	1.82	1.55	1.90	-1.35
Education and health care services	5.07	1.40	2.24	1.46	-0.03
Industry median	4.54	1.40	1.01	1.77	0.61

Source: Statistics Canada, Canadian Productivity Accounts.

Capital accumulation is the dominant source of output growth in the two natural resources industries (mining and oil and gas extraction; and utilities) as would be expected. The other sectors where capital is important are the finance, insurance and real estate industries.

In the mining and oil and gas extraction industries, capital contributed 2.7 percentage points or 78.5% of output growth, compared with 0.3 percentage points from labour, 1.5 percentage points from intermediate inputs, and -1.0 percentage points from MFP growth.

In the utilities industries, which include electrical power generation, transmission and distribution, and natural gas distribution, the contribution from capital was 2.1 percentage points, compared with 0.5 percentage points from labour, 1.0 percentage points from intermediate inputs, and 1.0 percentage points from MFP growth.

Labour input is the most important contributor to output growth in professional, scientific and technical services and education and health care services industries. Those two industries are labour-intensive industries. But even there, capital is an important source of output growth. In the professional services industries, the contribution to output growth from labour was 3.1 percentage points, compared with 3.0 percentage points from capital, 2.5 percentage points from intermediate inputs, -1.9 percentage points from MFP growth.

The two distributive trades industries (retail and wholesale) have relatively higher contributions from labour than capital.

Intermediate inputs are the dominant source of output growth in three goods industries (agriculture; manufacturing; and construction) and three services industries (wholesale trade; retail trade; and transportation). The agriculture and manufacturing industries are intermediate-input intensive. Over the period from 1961 to 2002, about 70% of output growth can be attributed to intermediate inputs in the agriculture and manufacturing industries.

There has been rapid technological change in the agriculture, transportation and information industries. As a result, MFP growth was an important contributor to output growth in those three industries. Over the period from 1961 to 2002, more than 20% of output growth came from MFP growth in those industries.

Standard growth accounting techniques can be used to examine the sources of industry-level labour productivity growth. Labour productivity growth is decomposed into contributions from capital deepening, intermediate input deepening, labour compositional changes and MFP growth.

Table 12 and Figure 11 present the decomposition of labour productivity growth for the 13 industries of the business sector over the period from 1961 to 2002. When comparing the contribution of two investment aggregates with the contribution of MFP growth, we find that investment in tangible assets and human capital made a similar or more important contribution to labour productivity growth in almost all industries except in the manufacturing, wholesale trade, retail trade, transportation, and communication industries.

In two natural resources industries (mining and utilities industries) where capital contributions are high, capital deepening is the dominant source of labour productivity growth. This reflects the well-documented evidence that the firms in natural-resource industries often buy technologically advanced equipment to improve productivity performance (Conference Board of Canada, 2001).

In finance, insurance, real estate and renting and leasing, professional services, education and health care, and other service industries, capital deepening is more important than MFP for labour productivity growth. In those industries, investment and capital deepening made a positive contribution to labour productivity growth while MFP growth made a negative contribution.

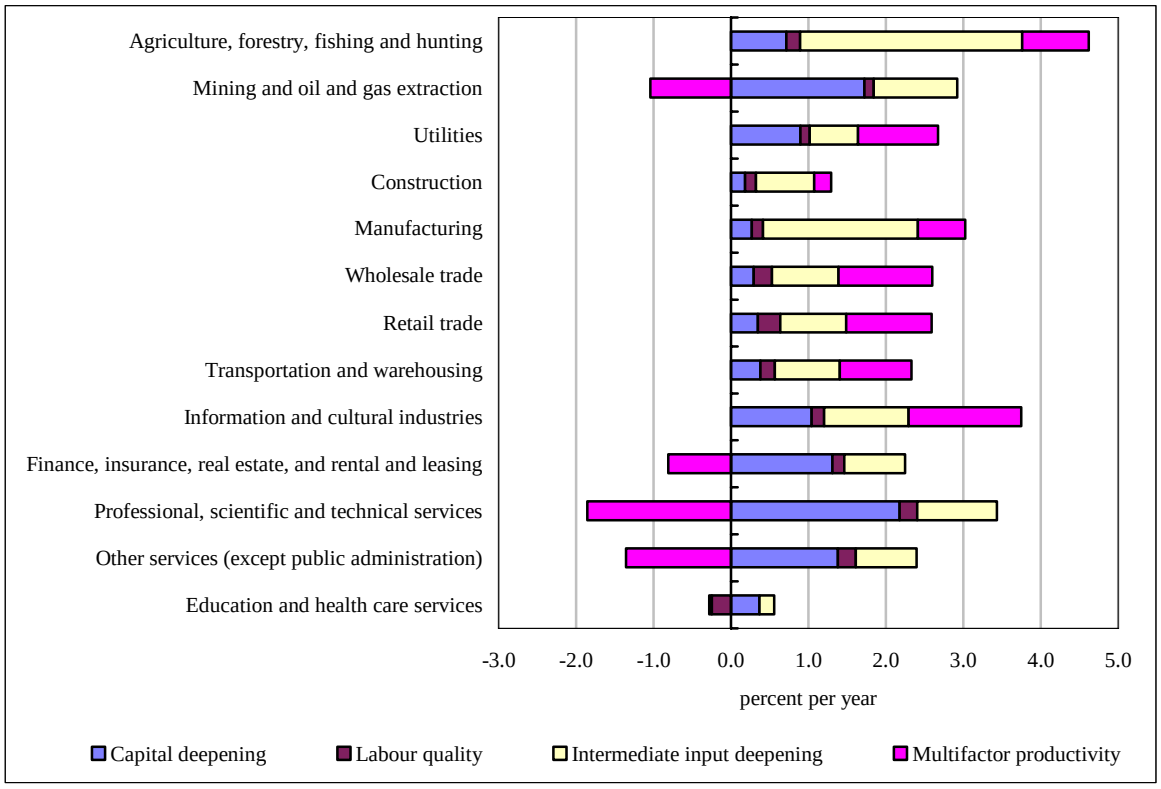
In wholesale trade, retail trade, and manufacturing industries, investment in tangible assets and worker skills was less important than MFP growth for labour productivity growth.

Table 12
Sources of labour productivity growth by industry, 1961 to 2002

	Labour productivity	Capital deepening	Labour quality	Intermediate input deepening	Multifactor productivity
	percent per year				
Agriculture, forestry, fishing and hunting	4.62	0.72	0.18	2.87	0.86
Mining and oil and gas extraction	1.88	1.72	0.12	1.08	-1.04
Utilities	2.67	0.90	0.12	0.62	1.03
Construction	1.30	0.18	0.14	0.76	0.22
Manufacturing	3.03	0.27	0.14	2.00	0.61
Wholesale trade	2.60	0.29	0.23	0.86	1.21
Retail trade	2.59	0.35	0.29	0.85	1.10
Transportation and warehousing	2.33	0.38	0.18	0.84	0.92
Information and cultural industries	3.75	1.05	0.16	1.09	1.45
Finance, insurance, real estate, and rental and leasing	1.44	1.31	0.15	0.78	-0.81
Professional, scientific and technical services	1.58	2.18	0.23	1.03	-1.85
Other services (except public administration)	1.04	1.38	0.23	0.78	-1.35
Education and health care services	0.27	0.37	-0.25	0.19	-0.03
Industry median	2.33	0.72	0.16	0.85	0.61

Source: Statistics Canada, Canadian Productivity Accounts.

Figure 11
Sources of labour productivity growth by industry, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

In transportation and information industries, there have been rapid technological changes. As a result, MFP growth and technological process are much more important contributors to labour productivity growth than capital deepening. Over the period from 1961 to 2002, these two industries have among the highest MFP growth rates among the 13 industries. In information and cultural industries, MFP increased at an annual rate of 1.5% and accounted for about 38.8% of labour productivity growth. In transportation industries, MFP increased at 0.9% per year and accounted for about 39.6% of labour productivity growth.

In conclusion, the contributions to labour productivity growth differ substantially across industries. In some, capital deepening is the dominant contributor to labour productivity growth. But in these industries, there is no consistent pattern as to whether multifactor productivity growth makes higher or even positive contributions to labour productivity growth. Increasing the quality of the labour force is important in most industries—though less important than MFP. There is also less variability in the contribution of skill upgrading across industries than there is in either capital deepening or in MFP growth. The knowledge economy is being felt across all industries (see Baldwin and Beckstead, 2003).

4.3 Output and productivity growth of new economy and natural resource industries

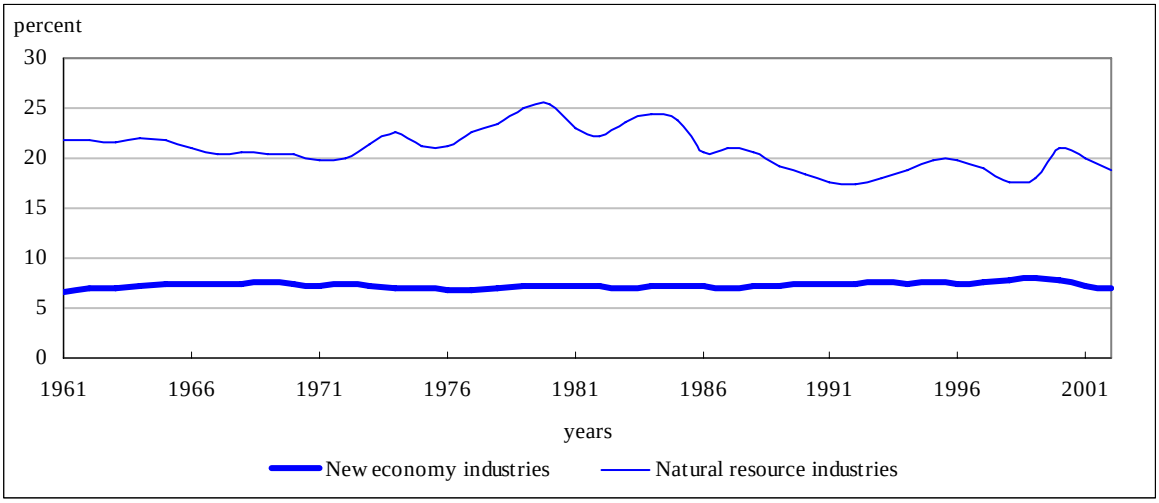
Much discussion has taken place about the role of new economy industries and natural resources industries in the Canadian economy (Beckstead and Gellatly, 2003, 2004; Sharpe, 2003; Conference Board of Canada, 2001; Keay, 2006; Ho, Rao and Tang, 2004). In this section, we compare output and productivity growth of the new economy and natural resources industries.

The new economy is often identified as those industries that electronically capture, transmit and display information (Statistics Canada, 2001, Nordhaus, 2002). Using this definition, we include in the new economy industries the following North American Industry Classification System (NAICS) industries: industrial machinery and equipment manufacturing (NAICS 333); computer and electronic product manufacturing (NAICS 334); and information and cultural industries (NAICS 51). The new economy industries are often called the information and communication technology-producing industries (Beckstead and Gellatly, 2003).[18]

The natural resource sector covers both primary industries and resource-based manufacturing industries. We include in the natural resource sector the following industries: forestry, logging; fishing and hunting and trapping; mining and oil and gas extraction; electrical power generation, transmission and distribution; natural gas distribution; seafood; wood product; paper manufacturing; non-metallic mineral products; primary metals; and fabricated metal products. Sharpe (2003) and Keay (2006) have adopted a similar definition in their studies on the Canadian natural resource sector.

18. Beckstead and Gellatly, 2003 have also adopted a broader definition of new economy industries that includes all science-based goods and services industries.

Figure 12
Share of new economy and natural resource industries in nominal gross domestic product, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

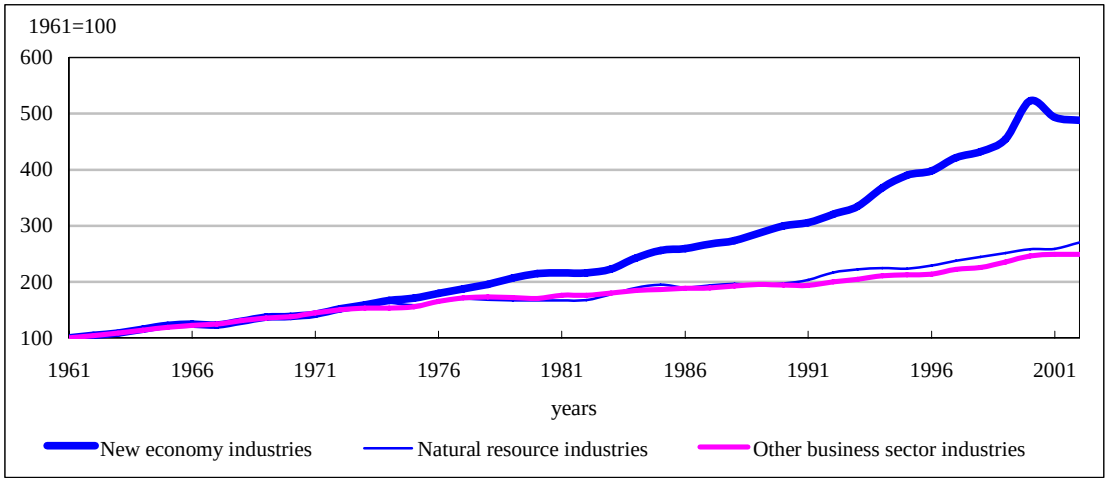
Figure 12 plots the share of new economy industries and natural resource industries in business sector GDP. The share of new economy industries in the business sector is small and has shown little change over time. Over the period from 1961 to 2002, new economy industries accounted for between 7% and 8% of nominal GDP in the Canadian business sector.

Natural resource industries were more important than new economy industries in terms of their contribution to nominal GDP in Canada. In 2002, the natural resource sector accounted for 18.8% of nominal GDP in the total business sector.

The output share of natural resource sectors showed large fluctuations over time. It increased between the early 1970s and the 1980s. In the 1980s, the share of natural resource industries declined due to weak demand. The share rebounded in the 1990s.

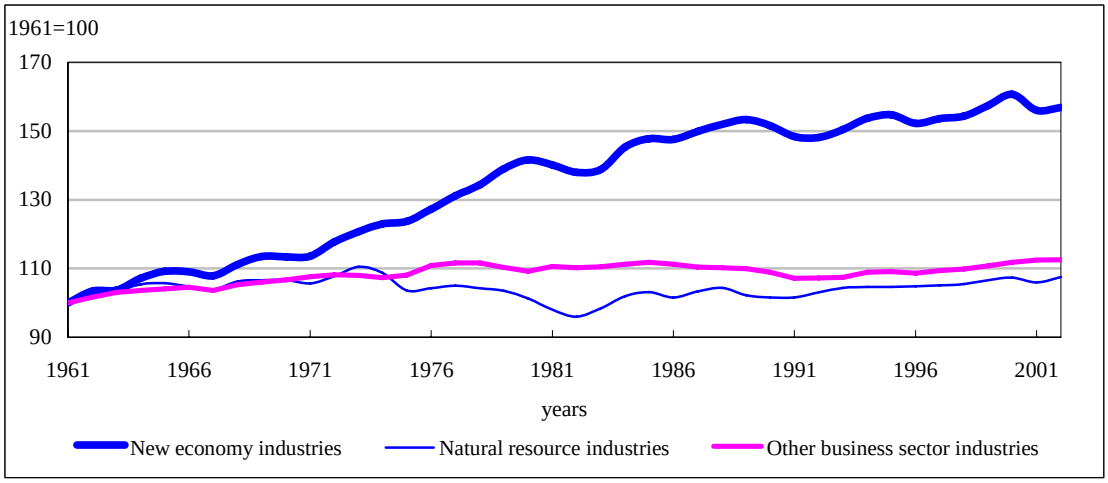
Figures 13a and 13b plot labour productivity and multifactor productivity in new economy industries, natural resource industries and other business sector industries. New economy industries had the highest labour productivity and multifactor productivity growth over the 1961-to-2002 period. Natural resource industries had the second-highest labour productivity growth, but their multifactor productivity growth is lower than that of the other business sector industries.

Figure 13a
Labour productivity in new economy industries, natural resource industries, and other business sector industries, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

Figure 13b
Multifactor productivity in new economy industries, natural resource industries, and other business sector industries, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

Table 13 presents the decomposition results of output growth and labour productivity growth in new economy industries, natural resource industries and other business sector industries. Over the period from 1961 to 2002, annual labour productivity growth was 3.9% in new economy industries, compared with 2.4% in natural resource industries, and 2.2% in the rest of the business sector. Annual MFP growth was 1.1% in new economy industries, 0.2% in natural resource industries, and 0.3% in the rest of the business sector.

Table 13
Sources of output and labour productivity growth in new economy and natural resource industries, and other business sector industries, 1961 to 2002

Sources of output growth	Gross output	Capital	Labour	Intermediate inputs	Multifactor productivity
	percent per year				
New economy industries	5.79	1.23	0.77	2.69	1.10
Natural resource industries	3.12	0.94	0.30	1.70	0.18
Other business sector industries	4.07	0.87	0.86	2.05	0.29
Sources of labour productivity growth	Labour productivity	Capital deepening	Labour quality	Intermediate input deepening	Multifactor productivity
	percent per year				
New economy industries	3.87	0.79	0.18	1.80	1.10
Natural resource industries	2.42	0.75	0.15	1.35	0.18
Other business sector industries	2.23	0.55	0.25	1.14	0.29

Source: Statistics Canada, Canadian Productivity Accounts.

The sources of output and labour productivity growth differ between natural resource industries and new economy industries. Capital deepening is a more important source of output and productivity growth in natural resource industries than in new economy industries. Capital input growth contributed 30.2% of output growth and 31.1% of labour productivity growth in natural resource industries over the period from 1961 to 2002. In contrast, capital input growth contributed 21.2% of output growth and 20.4% of labour productivity growth in new economy industries.

During the last four decades, technological process has been more rapid in new economy industries than in natural resource industries. MFP growth represents a more important source of output and productivity growth in new economy industries than in natural resource industries. Over the period from 1961 to 2002, MFP growth contributed 19.0% of output growth and 28.4% of labour productivity growth in new economy industries. MFP growth contributed 5.6% of output growth and 7.2% of labour productivity growth in natural resource industries over the same period.

Labour compositional changes contributed 0.2 percentage points or 4.6% of labour productivity growth in new economy industries. It contributed 0.2 percentage points or 6.2% of labour productivity growth in natural resource industries. Increases in worker skills and investments in human capital are a significant source of labour productivity growth in both new economy industries and natural resource industries.

Intermediate input deepening made a larger contribution to labour productivity growth in natural resource industries than in new economy industries. Over the 1961-to-2002 period, 55.5% of labour productivity growth in natural resource industries can be attributed to intermediate input deepening, while 46.6% of labour productivity growth in new economy industries can be attributed to intermediate input deepening.

4.4 Industry contributions to aggregate productivity growth

Aggregate productivity growth in the business sector can be traced to its origins at the industry level. This section quantifies the contributions of industries to aggregate labour and multifactor productivity growth in the business sector.

The methodology for the decomposition of aggregate MFP growth is Domar aggregation. Domar shows that aggregate MFP growth can be expressed as a weighted average of industry MFP growth:

$$(26) \qquad \dot{MFP} = \sum_i \bar{w}_i \dot{MFP}_i, \quad \bar{w}_i = \frac{1}{2}\left(\frac{P_{it}Q_{it}}{P_tA_t} + \frac{P_{it-1}Q_{it-1}}{P_{t-1}A_{t-1}} \right),$$

where $\bar{w}_i$ is the Domar weight which is equal to a two-period average value of the ratio of nominal industry gross output to nominal aggregate value-added. A distinctive feature of Domar weights is that they sum up to more than one when industry-level MFP is calculated using gross output. This reflects the different output concepts that are used at the aggregate and industry level. Multifactor productivity, when measured at the aggregate level, is based on the value-added output concept, while MFP, measured at the industry level, is based on the gross output concept.

A methodology for decomposing aggregate labour productivity growth is developed by Stiroh (2002). He shows that aggregate labour productivity growth can be expressed as a weighted sum of industry labour productivity growth plus a term that reflects the effect of reallocation of hours on aggregate labour productivity growth:

$$(27) \qquad \dot{LP} = \sum_i \bar{\alpha}_i \dot{LP}_i + residual, \quad \bar{\alpha}_i = \frac{1}{2}\left(\frac{P_{it}A_{it}}{P_tA_t} + \frac{P_{it-1}A_{it-1}}{P_{t-1}A_{t-1}} \right),$$

where $\bar{\alpha}_i$ is a two-period average share of industry value-added in aggregate value-added, the residual term captures the effect of reallocation of hours across industries on aggregate labour productivity growth. The reallocation term is positive if industries with higher labour productivity levels experience higher growth of hours worked.

Tables 14 and 15 present industry contributions to labour and multifactor productivity growth in the business sector for the period from 1961 to 2002 and four sub-periods: 1961 to 1973, 1973 to 1979, 1979 to 1989, and 1989 to 2002.

Table 14
Industry decomposition of labour productivity growth, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Business sector	**2.16**	**3.50**	**2.00**	**1.30**	**1.66**
Agriculture, forestry, fishing and hunting	0.19	0.40	0.09	0.12	0.09
Mining and oil and gas extraction	0.04	0.28	-0.42	-0.02	0.07
Utilities	0.08	0.17	0.01	0.03	0.06
Construction	0.12	0.05	0.44	0.12	0.04
Manufacturing	0.77	1.15	0.76	0.46	0.66
Wholesale trade	0.16	0.12	0.07	0.30	0.14
Retail trade	0.20	0.29	0.20	0.11	0.17
Transportation and warehousing	0.18	0.38	0.16	0.09	0.06
Information and cultural industries	0.14	0.16	0.25	0.12	0.10
Finance, insurance, real estate, and rental and leasing	0.15	0.01	0.12	0.08	0.33
Professional, scientific and technical services	0.03	0.01	0.02	0.04	0.05
Other services (except public administration)	0.03	0.05	0.07	-0.03	0.04
Education and health care services	0.00	0.04	0.03	-0.03	-0.03
Residual effect	0.07	0.39	0.20	-0.11	-0.14
Special aggregation					
Goods sector	1.20	2.05	0.88	0.73	0.93
Services sector	0.89	1.06	0.92	0.69	0.87
New economy industries	0.27	0.29	0.41	0.24	0.23
Natural resource industries	0.48	0.86	-0.07	0.46	0.40
Other business sector industries	1.52	2.33	1.74	0.87	1.17

Source: Statistics Canada, Canadian Productivity Accounts.

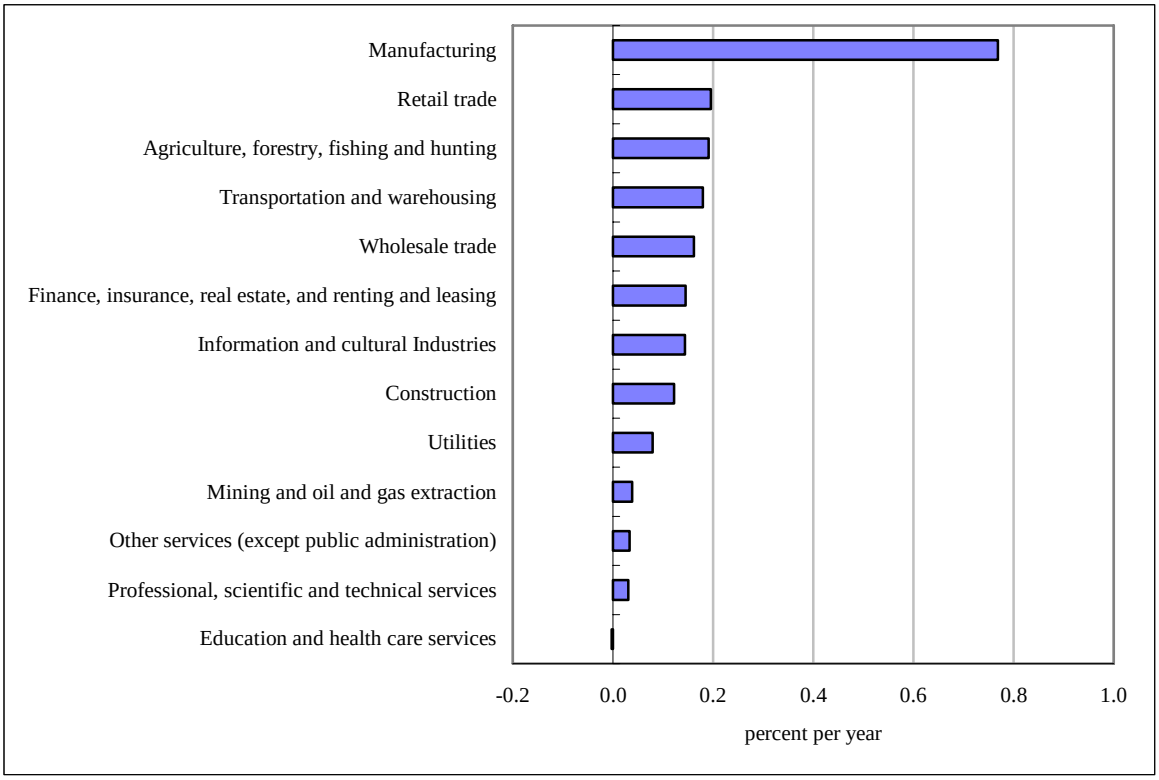
Table 15
Industry decomposition of multifactor productivity growth, selected periods, 1961 to 2002

	1961 to 2002	1961 to 1973	1973 to 1979	1979 to 1989	1989 to 2002
	percent per year				
Business sector	0.56	1.44	0.22	-0.09	0.42
Agriculture, forestry, fishing and hunting	0.10	0.21	-0.06	0.13	0.04
Mining and oil and gas extraction	-0.13	0.06	-0.53	-0.21	-0.06
Utilities	0.04	0.09	-0.03	0.00	0.06
Construction	0.05	-0.03	0.29	0.08	-0.01
Manufacturing	0.46	0.78	0.46	0.17	0.39
Wholesale trade	0.11	0.11	0.03	0.21	0.08
Retail trade	0.13	0.23	0.11	0.04	0.09
Transportation and warehousing	0.11	0.29	0.13	0.05	-0.01
Information and cultural industries	0.07	0.11	0.18	0.06	0.00
Finance, insurance, real estate, and rental and leasing	-0.13	-0.26	-0.18	-0.27	0.13
Professional, scientific and technical services	-0.08	-0.09	-0.08	-0.09	-0.05
Other services (except public administration)	-0.16	-0.27	-0.15	-0.19	-0.03
Education and health care services	-0.01	0.03	0.04	0.00	-0.08
Residual effect	0.00	0.18	0.00	-0.07	-0.12
Special aggregation					
Goods sector	0.52	1.11	0.13	0.17	0.42
Services sector	0.05	0.15	0.09	-0.18	0.12
New economy industries	0.14	0.20	0.29	0.12	0.03
Natural resource industries	0.06	0.37	-0.52	-0.08	0.15
Other business sector industries	0.40	0.88	0.48	-0.06	0.28

Source: Statistics Canada, Canadian Productivity Accounts.

Figure 14 ranks industries by their contribution to aggregate labour productivity growth in the 1961-to-2002 period. All industries except the education and health sector made a positive contribution to aggregate labour productivity growth. The manufacturing sector made the most important contribution to aggregate labour productivity growth (0.77 percentage points), followed by retail trade (0.20), the agriculture, forestry, fishing and hunting sector (0.19), transportation (0.18), wholesale trade (0.16), and finance, insurance, real estate, and rental and leasing (0.15).

Figure 14
Industry contributions to labour productivity growth, 1961 to 2002

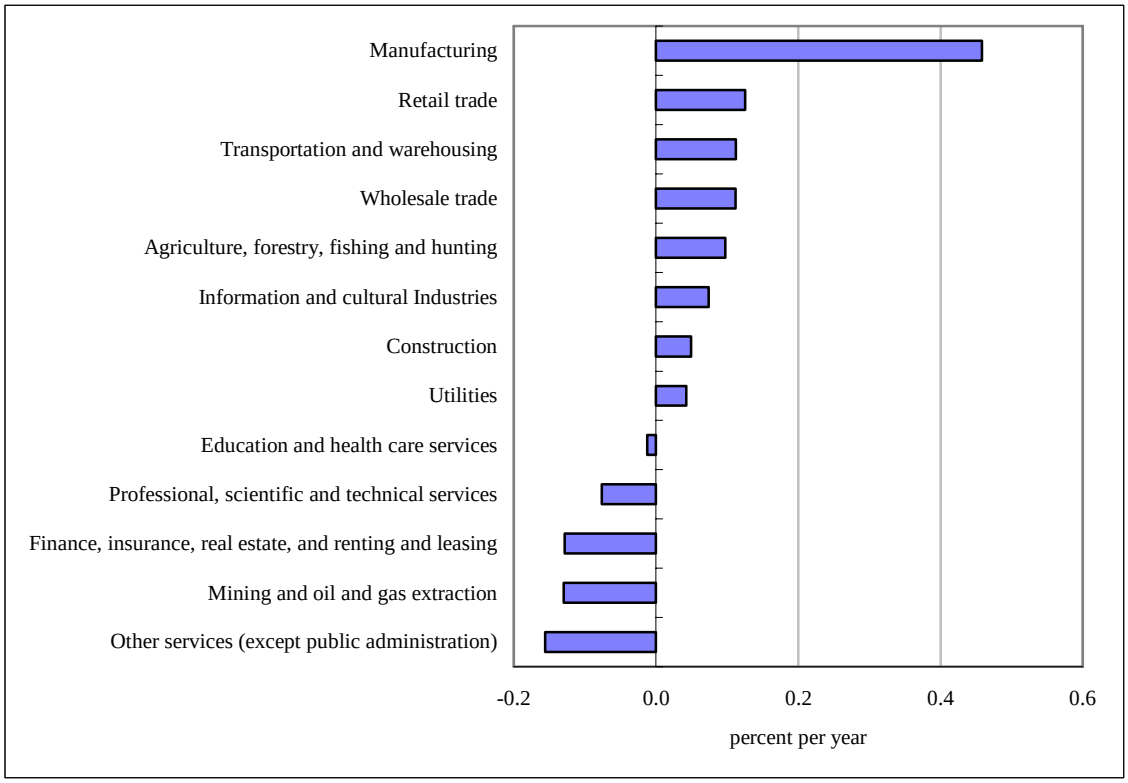


Source: Statistics Canada, Canadian Productivity Accounts.

Figure 15 ranks industries by their contribution to aggregate multifactor productivity growth in the 1961 to 2002 period. This picture echoes Figure 14 on aggregate labour productivity growth. Again, the manufacturing sector made the largest contribution (0.46 percentage points), followed by retail trade (0.13), transportation (0.11), wholesale trade (0.11), agriculture, forestry, fishing and hunting sector (0.10), information and cultural industries (0.07).

Five industries made a negative contribution to aggregate MFP growth over the period from 1961 to 2002. Those five industries consists of four services industries (education and health care services; professional services; finance, insurance, real estate; and other services) and one goods industries (mining and oil and gas extraction).

Figure 15
Industry contributions to multifactor productivity growth, 1961 to 2002



Source: Statistics Canada, Canadian Productivity Accounts.

As shown in Table 14, the goods sector has made a disproportionately larger contribution to aggregate labour productivity growth than the services sector. The goods sector contributed 1.20 percentage points or about 55.6% of the aggregate labour productivity growth, while the services sector contributed 0.89 percentage points or 41.1%.[19] The contribution of the goods sector to aggregate labour productivity is larger than its share of nominal GDP, which is on average 49% in the 1961-to-2002 period.

The goods sector has also been the most important source of MFP growth in the business sector (Table 15). The good sector contributed 0.52 percentage points to aggregate MFP growth in the 1961-to-2002 period, while the services sector made a small contribution to aggregate MFP growth (0.05 percentage points). While the overall contribution of the services sector to aggregate MFP growth is small, the wholesale trade, retail trade, transportation, and information industries have made large positive contributions to aggregate MFP growth over the period from 1961 to 2002.

Over the period from 1961 to 2002, the new economy sector was a less important source of aggregate labour productivity growth than the natural resource sector. However, the new economy sector had much faster MFP growth, and made a larger contribution to aggregate MFP

19. The remainder is the effect of reallocation of hours which made a positive contribution. This suggests that there is a shift of hours toward the industries with high labour productivity over the period.

growth than the natural resource sector. In the period from 1961 to 2002, new economy industries contributed 0.27 percentage points to labour productivity growth, while natural resource industries contributed 0.48 percentage points. The new economy industries contributed 0.14 percentage points to MFP growth, while natural resource industries contributed 0.06 percentage points. The difference in the contributions then comes not from the relative growth rates but from the relative size of the two sectors. Aggregate growth at the country level depends heavily on industrial composition.

4.5 Industry contributions to changes in aggregate productivity growth

After strong growth in the 1961-to-1973 period, productivity growth in the business sector experienced two significant declines, one in the period 1973 to 1979 and the second in 1979 to 1989. Since 1989, aggregate productivity growth has shown a marked rebound. This section analyzes the industry origins of changes in aggregate productivity growth over time.

Table 16 presents the industry contribution to changes in aggregate labour productivity growth. Labour productivity growth in the business sector declined by 1.49 percentage points per year between the 1961-to-1973 and 1973-to-1979 periods. The decline was much faster in the goods sector than in the services sector, and much faster in the natural resource sector than in other business sectors.

Table 16
Industry decomposition of changes in labour productivity growth

	1973 to 1979 less 1961 to 1973	1979 to 1989 less 1973 to 1979	1989 to 2002 less 1979 to 1989
	percent per year		
Business sector	-1.49	-0.70	0.36
Agriculture, forestry, fishing and hunting	-0.31	0.03	-0.03
Mining and oil and gas extraction	-0.70	0.40	0.09
Utilities	-0.16	0.02	0.03
Construction	0.39	-0.31	-0.08
Manufacturing	-0.39	-0.30	0.19
Wholesale trade	-0.05	0.23	-0.16
Retail trade	-0.09	-0.08	0.06
Transportation and warehousing	-0.22	-0.07	-0.03
Information and cultural industries	0.09	-0.13	-0.02
Finance, insurance, real estate, and rental and leasing	0.11	-0.04	0.26
Professional, scientific and technical services	0.00	0.02	0.01
Other services (except public administration)	0.02	-0.10	0.07
Education and health care services	-0.01	-0.06	0.00
Residual effect	-0.19	-0.32	-0.03
Special aggregation			
Goods sector	-1.17	-0.15	0.20
Services sector	-0.13	-0.24	0.18
New economy industries	0.12	-0.17	-0.01
Natural resource industries	-0.93	0.53	-0.06
Other business sector industries	-0.59	-0.87	0.30

Source: Statistics Canada, Canadian Productivity Accounts.

The decline in productivity growth in the goods sector was largely responsible for the labour productivity growth slowdown after 1973. The results in Table 16 show that the goods sector contributed 1.17 percentage points to the post-1973 productivity growth slowdown while the services sector contributed 0.13 percentage points. When we divide industries into new economy industries, natural resource industries and other industries, we find that natural resource industries accounted for 0.93 percentage points of the aggregate labour productivity growth slowdown between 1961 to 1973 and 1973 to 1979.

The business sector labour productivity growth showed a second decline in the 1979-to-1989 period. It declined by 0.70 percentage points between the 1973-to-1979 and 1979-to-1989 periods. The industry origins of this second decline of labour productivity growth are different from the first decline. The second decline of labour productivity growth can be traced to its origins in both the goods sector and services sector. The goods sector contributed 0.15 percentage points to the second decline and the services sector contributed 0.24 percentage points.

Labour productivity growth in the business sector has shown a marked pickup since 1989. It increased by 0.36 percentage points between 1979 to 1989 and 1989 to 2002. The goods sector contributed 0.20 percentage points and the services sector 0.18 percentage points. Surprisingly, the new economy sector was not a factor behind the post-1989 acceleration in labour productivity growth. The other industries of the business sector were responsible for this productivity growth acceleration.

Table 17 presents industry contributions to changes in aggregate multifactor productivity growth. The results on the sources of MFP growth echo those on the sources of labour productivity growth. The decline in MFP growth in the goods sector was responsible for most of the first MFP growth deceleration between 1961 to 1973 and 1973 to 1979. The second decline of MFP growth between 1973 to 1979 and 1979 to 1989 can be traced to its origins in the services sector. The recent pickup in MFP growth in the 1989 to 2002 period occurred in both the goods and services sector, but did not occur in the new economy sector.

Once again, productivity fluctuations at the level of the aggregate economy cannot be attributed to a particular sector or a particular industry throughout the period. The identity of individual industries whose productivity growth rates slow down changes over periods—thereby indicating that the changes that are occurring are idiosyncratic and industry specific. Technological change does not have its impact felt consistently across the industry set. And those who start ahead in one period are not there in the next.

Table 17
Industry decomposition of changes in multifactor productivity growth

	1973 to 1979 less 1961 to 1973	1979 to 1989 less 1973 to 1979	1989 to 2002 less 1979 to 1989
	percent per year		
Business sector	-1.22	-0.31	0.51
Agriculture, forestry, fishing and hunting	-0.28	0.19	-0.08
Mining and oil and gas extraction	-0.58	0.32	0.15
Utilities	-0.12	0.03	0.05
Construction	0.33	-0.21	-0.09
Manufacturing	-0.33	-0.29	0.22
Wholesale trade	-0.07	0.18	-0.14
Retail trade	-0.12	-0.07	0.05
Transportation and warehousing	-0.15	-0.08	-0.07
Information and cultural industries	0.07	-0.11	-0.06
Finance, insurance, real estate, and rental and leasing	0.09	-0.09	0.39
Professional, scientific and technical services	0.01	-0.02	0.04
Other services (except public administration)	0.12	-0.04	0.16
Education and health care services	0.01	-0.05	-0.08
Residual effect	-0.18	-0.07	-0.05
Special aggregation			
Goods sector	-0.98	0.04	0.25
Services sector	-0.05	-0.27	0.30
New economy industries	0.09	-0.17	-0.09
Natural resource industries	-0.89	0.44	0.23
Other business sector industries	-0.40	-0.53	0.34

Source: Statistics Canada, Canadian Productivity Accounts.

5. Summary

This paper makes use of the databases at the heart of the Canadian Productivity Accounts to examine the sources of growth in the Canadian economy and the history of productivity growth in Canada over the period from 1961 to 2002. It employs new time series using the North American Industry Classification System.

The growth accounting system provides the framework for the analysis. This analysis, based on a production framework, decomposes output growth into the portion that comes from increases in labour and capital and a residual (entitled multifactor productivity) that captures the component that is not directly related to the increasing use of labour and capital.

Measures of multifactor productivity (MFP) growth are often used to assess the rate of growth of technological progress. They are of intrinsic interest because consumers benefit directly from higher productivity growth in terms of lower prices. Baldwin et al. (2001) show that on a cross-section basis, industries with higher multifactor productivity growth have the lowest rate of price increases. Successful productivity growth also affects an industry's international competitive advantage. Baldwin and Yan (2006) demonstrate that, at the industry level, changes in the

relative Canada–U.S. price are inversely related to estimates of changes in relative multifactor productivity in Canada and the United States.

The growth accounting framework provides estimates of the relative importance of labour inputs, investments in capital and productivity growth. The data that are required to address this issue also allow changes in the composition of capital and labour inputs to be investigated. In addition, the underlying factors that determine labour productivity (multifactor productivity, capital deepening, and increases in skill level) can be measured. Since the database is constructed at the industry level, all these relationships can be pursued both at the level of the total economy and for individual industries.

Several questions are posed in this section of the paper.

1. What has been the history of productivity growth over the period?

Estimates of annual productivity growth have fluctuated considerably over time. They are quite volatile in the short run. They are often high at the end of the business cycle and fall during recessions and slowdowns. This makes interpretation of short-run trends difficult. Moreover, short-run averages are extremely sensitive to the choice of endpoints. Analysts who wish to argue that crises exist can use the high points just before the end of a business cycle and the low points at middle of recessions.

There are, however, discernible long-run trends in Canadian productivity growth—both labour and multifactor productivity. There was a long decline from the early 1960s to 1990. Since then, productivity growth has picked up. The break point appears to correspond with the start of the 1990s—the decade when investments in information and communications technologies (ICT) began to receive so much attention. It is significant that both productivity and output growth trends are correlated. Higher output growth is generally accompanied by higher productivity growth. This could either be because high growth periods make the introduction of new technologies easier or that rapid technological change fans higher growth rates.

A word of caution is, however, required here. High output growth rate industries are not necessarily those industries with the highest labour productivity growth. At the industry level, high growth does not necessarily translate into higher productivity or vice versa.

2. What types of capital are used in the growth process?

In 2002, the largest component of aggregate capital services was machinery and equipment outside of information and communications technologies (non-ICT M&E), followed by building structures and engineering structures. Non-ICT M&E accounted for 27.0% of aggregate capital services in 2002, building structure capital accounted for 24.3% of aggregate capital services, while engineering structure capital, 18.3% of capital services. It should be noted that the latter two made up over 42.0% of the total—much more than the machinery and equipment component. Capital consists of a great deal more than machinery and equipment—and most of the capital that workers have to work with comes in forms other than machinery and equipment.

The share of capital input accounted for by non-ICT M&E remained virtually unchanged over time. The share of the remaining assets (building structures, land and inventories) declined during the period from 1961 to 2002. The decline in inventory's share has been associated with the application of just-in-time production methods. The decline for buildings and engineering structures has been the result of long-term increases in capital productivity in those sectors that make the most use of this type of infrastructure investment—transportation, communications, utilities, and water (see Baldwin and Dixon, 2007).

There has been a long-term shift in capital services towards M&E and away from structure capital, land and inventories in the Canadian business sector. Of M&E capital, ICT increased the most. Over the period from 1961 to 2002, ICT capital increased at an annual rate of 14.1%. The dramatic increases in ICT capital services occurred as the price of ICT capital declined relative to other forms of capital. Canadian businesses have made large investments in ICT to take advantage of the dramatic decline in the price of ICT capital.

3. What types of labour are used in the growth process?

Since 1961, the composition of the labour forces has changed dramatically (Gu et al. [2002]). From 1961 to 1979, the share of younger workers (less than 25 years) first increased dramatically and then fell continuously until the mid-1990s. As this group of post-war boomers aged, workers in the age group from 25 to 44 years, increased from the 1970s to the early 1990s and then declined. This long demographic cycle led first to a decline in the average experience of the workforce and more recently to an increase.

There have also been dramatic changes in the educational qualifications of the labour force. The percentage with only high school has fallen steadily, and those with post-secondary degrees has increased. For example, those with some post-secondary education increased from less than 10% in 1961 to over 40% by 2000.

The declining average age occasioned by additions of relatively large portions of younger workers early in the period, and then an increase in experienced workers later as these workers matured, led to quite opposite effects on the contribution to labour inputs that came from upgraded skills—what is termed labour composition in this paper. The effect of the changing level of experience occasioned by first a greening of the labour force and then its aging follows an inverted U—with first a decline coming from the experience component then an increase.

But the impact of changing experience in most periods is small. Far more important is the increase in the skill component that comes from increases in education levels. And since upgrading of education levels is more or less continuous during the period, this force provided most of the increase caught by the labour composition or quality component of labour input growth.

4. What is the relative contribution of capital, labour and productivity growth to economic growth?

The growth accounting framework decomposes output growth into three components—the growth in labour inputs, the growth in capital inputs and multifactor productivity (MFP). Output needs labour and capital inputs and growth in output can be constrained by shortages of either of these factor inputs. In a world where population growth is constraining future increases in employment, maintaining present growth rates will depend on whether growth rates in capital or multifactor productivity can be accelerated. Historical experience may give some indication of the possibilities for substitution here.

For the period from 1961 to 2002, output grew 3.9% per year in the business sector. Capital services contributed 1.8 percentage points or 47.3% of the business sector output growth. Labour input contributed 1.5 percentage points or 38.1% of the output growth. A good portion of the growth in both labour and capital came from changes in the composition of each aggregate—that is, the composition of the inputs changed from the less productive to more productive inputs over the period. The growth that is due to upgrading accounted for about one-third of total growth for both labour and capital.

Multifactor productivity growth was the least important source of output growth in the business sector and contributed 0.6 percentage points or 14.6% of the output growth. The growth in capital services then has been more important than the growth of labour over most of the period and offers possibilities for compensating for future reductions in the growth in labour that are expected to result from declining population growth in Canada.

Many factors influence the rate of growth in labour inputs—changing socio-economic factors that lead to higher labour force participation by women, increases in participation by older males, and immigration. Over the period studied, the growth rate in employment has decreased slowly. If these declines continue in the future, overall growth may fall unless capital or MFP growth increases. However, the historical record does not show that either of these components have increased enough over the last three decades to offset the decline in labour growth that has already occurred. The contribution made by the growth in capital has fallen over the period—by even more than the contribution of labour growth—starting in the 1980s and continuing into the 1990s. The residual, unmeasured category (multifactor productivity growth) has also declined since its high point in the 1961 to 1973 period—though, there is evidence this decline reached its low point at the end of the 1980s and has recently begun to rise.

Nevertheless, the average growth in multifactor productivity over most of the period has not been large—especially compared to the growth in labour inputs. And it is less obvious that increases in this component are likely to offset future declines in the growth of labour.

For those who wish to compare Canadian MFP estimates to those of other countries, it should be remembered that the Canadian Productivity Accounts calculate the labour and capital inputs with ‘quality’ components included. That is, the Accounts do not just sum hours worked across all groups of workers or sum capital across all asset types. The Accounts calculate weighted averages of the growth in hours worked using 56 different categories of workers and 28 different

types of assets. By doing so, the Canadian Productivity Accounts take into account the different productivity of inputs. The difference between the weighted growth rate of the different inputs and the simple sum of all hours or all capital is referred to as the effect of the changing composition of labour or capital—the labour and the capital composition effect, respectively. This procedure yields substantially higher estimates of the growth in factor inputs (labour and capital) and concomitantly lowers estimates of multifactor productivity growth.

For example, the labour composition effect averaged 0.7% annually from 1961 to 2002. This translates into an average of about 0.5% annually when multiplied by the share of labour to give the contribution to output growth of shifts in labour composition towards more skilled workers. The same capital composition effect averaged around 1.5% per year, which is about 0.6% per year when multiplied by capital's share to give the contribution that shifts in capital composition to more productive assets had on output growth. If these two composition effects were added back into the multifactor productivity estimate of 0.6% annually, the uncorrected multifactor productivity estimate would increase to 1.6% per year—an increase of almost 300%. It is important then to take into account the heterogeneity of factor inputs—for it changes the conclusions that can be drawn from the growth accounting framework. We conclude here that most of the growth came from increased factor inputs—not from disembodied technological progress. If we had not corrected for the changing quality of factor inputs, we would have drawn the opposite conclusion.

If we are to rely on higher rates of multifactor productivity growth in the future to maintain economic growth rates, we need to forecast whether increases are possible and whether they are sustainable. The historical record does not suggest large increases are likely. It also does not suggest they are very sustainable. The contributions of labour and capital are much more stable than is multifactor productivity. Multifactor productivity growth is largest in the 1961-to-1973 period. It is lowest in the 1979-to-1989 period. The growth in capital services, though in decline, was generally more important than the growth in labour services. Together the growth rates in these two factor inputs have contributed over 1.0 percentage points of the 2.3 percentage points decline in output between the periods from 1961 to 1973 and 1973 to 2002. The rest of the decline comes from a much lower growth in multifactor productivity. However, between the 1980s and 1990s, while the growth in labour and capital inputs declined, multifactor productivity increased enough to substantially offset these declines.

5. How important are the various factors that determine the growth in labour productivity?

Growth in labour productivity is of interest because it is closely connected with changes in real wage rates over the long run.

For the 1961-to-2002 period, labour productivity grew at annual rate of 2.2% in the business sector. Capital deepening was the most important factor. It contributed 1.2 percentage points and 53.2% of the labour productivity growth. The change in labour composition was an important source of labour productivity growth in the business sector for the 1961-to-2002 period, contributing 0.5 percentage points or a quarter of labour productivity growth in the business sector. A positive labour composition effect captures the increase in the average educational attainment and experience levels of the workers. The importance of the labour composition

component therefore demonstrates that investments in education and training have made a significant contribution to labour productivity growth in Canada.

The contribution of ICT capital deepening to labour productivity growth showed a large increase over time. In the 1961 to 1973 period, little of capital's contribution to labour productivity was from ICT investment. In the 1989 to 2002 period, about 58.6% of the productivity contribution of capital services can be attributed to ICT capital deepening. And it is significant that it is during the latter period that multifactor productivity growth has once more picked up. This has been used by some to suggest that it is not so much increases in capital intensity as the type of capital that matters.

Multifactor productivity growth contributed the remaining 0.6 percentage points or 26.1% of labour productivity growth. MFP growth is often associated with technological change, organizational change, scale economies or changes in utilization rates.[20] While contributing substantially to labour productivity growth, its importance is nevertheless, in this framework, behind investment in general. But this type of conclusion needs to be qualified. The growth accounting framework decomposes contributions from different factors into separate and independent components for the purposes of simplicity. In the end, the types of technological change embedded into the multifactor productivity measure is no doubt a function of investments in new technologies, in new organizational forms, in new ways of doing business, and in research and development. A more detailed set of measures in all of these areas would just expand the list of types of capital assets that are behind technological progress.

In two of the periods, capital deepening and multifactor productivity have moved together. From 1961 to 1973, the contribution from both was high. From 1979 to 1989, both declined relative to earlier periods. This suggests that there are particular time periods when it is technology that is being driven by investment in the type of traditional assets that are measured in capital stock. In other periods (1973 to 1979), capital deepening is high but multifactor productivity was nevertheless lower, thereby suggesting that traditional investments were not sufficient conditions in this sense for technological progress—that there may have been deficiencies in this period in the complementary expenditures that are required for change.

6. What are the differences in growth profiles at the industry level?

This paper also examines industry performance using the growth framework at the industry level. It asks whether the trends depicted at the level of the total economy are widespread or concentrated only in the largest industries. The investigation posed several questions:

6.1 Does most productivity growth come from one sector?

At the industry level, goods industries tend to have higher productivity growth than the services sectors. But there are exceptions to the rule. Information industries have had some of the highest

20. The studies on the determinants of productivity growth suggest that there is complementarity between physical capital, human capital and technical process (OECD, 1991; Gera, Gu and Lee, 1998). The normal growth accounting framework for examining the sources of labour productivity growth does not allow for this complementarity.

growth rates both in terms of labour and multifactor productivity. The information sector has benefited from the ICT revolution (Beckstead and Gellatly, 2003).

Over the entire period, high growth rates can be found in both goods and services—in information and transportation on one side and in manufacturing and agriculture on the other. Agriculture continues to shine in terms of productivity growth—a phenomenon that has continued throughout most of this century.

High growth occurs both in new economy and old economy industries. There are no easy generalizations about where productivity growth and technological change are highest. This suggests that technological advances are neither easy to predict nor easy to classify. They occur at different times, in different places.

6.2 Is the importance of capital accumulation uniform across industries?

The economy is made up of industries that range from highly capital intensive to more labour intensive. Capital accumulation is the dominant source of output growth in the two natural resources industries (mining and oil and gas extraction; and utilities), as would be expected. But the other sectors where capital is important are the finance, insurance and real estate industries. Labour input is the most important contributor to output growth in professional services, and education and health care services industries. Those two industries are labour-intensive industries. But even there, capital is an important source of output growth. In the professional services industries, the contribution to output growth from labour was 3.1 percentage points, compared with 3.0 percentage points from capital, 2.5 percentage points from intermediate inputs, and -1.9 percentage points from MFP growth. The two distributive trades industries (retail and wholesale) have relatively higher contributions from labour than capital.

6.3 Is capital deepening the prime contributor to labour productivity growth?

The contributions to labour productivity growth differ substantially across industries. In some, capital deepening is the dominant contributor to labour productivity growth. But in these industries, there is no consistent pattern as to whether multifactor productivity growth makes higher or even positive contributions to labour productivity growth. Increasing the quality of the labour force is important in most industries—though less important than MFP growth in most industries. And there is less variability across industries in the contribution of skill upgrading than there is in either capital deepening or in MFP growth. The growth in the knowledge economy is being felt across all industries (see Baldwin and Beckstead, 2003).

6.4 How do the new economy industries differ from the old economy industries?

The share of new economy industries in the business sector is small and has shown little change over time. Over the period from 1961 to 2002, new economy industries accounted for between 7% and 8% of nominal gross domestic product in the Canadian business sector. Natural resource industries were more important than new economy industries in terms of their contribution to nominal GDP in Canada. In 2002, the natural resource sector accounted for 18.8% of nominal GDP in the total business sector. New economy industries had the highest labour productivity

and multifactor productivity growth over the period from 1961 to 2002. Natural resource industries had the second-highest labour productivity growth, but their multifactor productivity growth is lower than that of the other business sector industries. Investment and capital deepening is a more important source of output and productivity growth in natural resource industries than in new economy industries. Technological progress has been more rapid in new economy industries than in natural resource industries.

6.5 Are fluctuations in the total economy's productivity growth coming primarily from one sector?

Productivity fluctuations at the level of the aggregate economy cannot be attributed to a particular sector or a particular industry throughout the period. The identity of individual industries, whose productivity growth rates decline, changes over periods—thereby indicating that the changes that are occurring are idiosyncratic and industry specific. Technological change does not have its impact felt consistently across the industry set.

References

Armstrong, P., T.M. Harchaoui, C. Jackson and F. Tarkhani. 2002. *A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies*. Economic Analysis Research Paper Series. Catalogue no. 11F0027MIE2002001. Ottawa: Statistics Canada.

Baldwin, J.R., D. Beckstead, N. Dhaliwal, R. Durand, V. Gaudreault, T.M. Harchaoui, J. Hosein, M. Kaci and J.-P. Maynard. 2001. *Productivity Growth in Canada.* Catalogue no. 15-204-XIE. Ottawa: Statistics Canada.

Baldwin, J.R., D. Beckstead and R. Caves. 2002. *Changes in the Diversification of Canadian Manufacturing Firms and Plants (1973-1997): A Move to Specialization*. Analytical Studies Branch Research Paper Series. Catalogue no. 11F0019MIE2002179. Ottawa: Statistics Canada.

Baldwin, J.R. and D. Beckstead. 2003. *Knowledge workers in Canada's economy, 1971-2001*. Insights on the Canadian Economy. Catalogue no. 11-624-MIE2003004. Ottawa: Statistics Canada.

Baldwin, J.R. and J. Chowhan. 2003. *The impact of self-employment on labour-productivity growth: A Canada and United States comparison*. Economic Analysis Research Paper Series. Catalogue no. 11F0027MIE2003016. Ottawa: Statistics Canada.

Baldwin, J.R. and J. Dixon. 2007. *Infrastructure: What is it? Where is it? How much of it is there?* Canadian Productivity Review Series. Catalogue no. 15-206-XIE. Ottawa: Statistics Canada. Forthcoming.

Baldwin, J.R., R. Durand and J. Hosein. 2001. "Restructuring and Productivity Growth in Canada." Chapter 2 in *Productivity Growth in Canada*. Catalogue no. 15-204-XIE. Ottawa: Statistics Canada.

Baldwin, J.R., V. Gaudreault and T.M. Harchaoui. 2001. "Productivity Growth in the Canadian Manufacturing Sector: A Departure from the Standard Framework." Chapter 8 in *Productivity Growth in Canada*. Catalogue no. 15-204-XIE. Ottawa: Statistics Canada.

Baldwin, J.R. and G. Gellatly. 2004. *Innovation Strategies and Performance in Small Firms*. Northhampton, Mass.: Elgar.

Baldwin, J.R. and W. Gu. 2007. *Multifactor Productivity in Canada: An Evaluation of Alternative Methods of Estimating Capital Services*. The Canadian Productivity Review. Catalogue no. 15-206-XIE2007009. Ottawa: Statistics Canada.

Baldwin, J.R. and T.M. Harchaoui (eds.). 2002. *Productivity Growth in Canada.* Catalogue no. 15-204-XIE. Ottawa: Statistics Canada.

Baldwin, J.R. and D. Sabourin. 2002. “Advanced technology use and firm performance in Canadian manufacturing in the 1990s.” *Industrial and Corporate Change*. 11, 4: 761–789.

Baldwin, J.R. and B. Yan. 2006. *Exchange Rate Cycles and Canada-U.S. Manufacturing Prices*. Economic Analysis Research Paper Series. Catalogue no. 11F0027MIE2006041. Ottawa: Statistics Canada.

Beckstead, D. and G. Gellatly. 2003. *The Growth and Development of New Economy Industries*. The Canadian Economy in Transition Series. Catalogue no. 11-622-MIE2003002. Ottawa: Statistics Canada.

Beckstead, D. and G. Gellatly. 2004. *Are Knowledge Workers Found only in High-technology Industries?* The Canadian Economy in Transition Series. Catalogue no. 11-622-MIE2004005. Ottawa: Statistics Canada.

Bureau of Labor Statistics. 1997. *BLS Handbook of Methods*. Bulletin 2490. Washington, DC: U.S. Department of Labor.

Conference Board of Canada. 2001. “Investing in Innovations in the Resource Sector.” Members’ Briefing 315-01.

Cross, P. 1996. *Alternative Measures of Business Cycles in Canada: 1947-1992*. Canadian Economic Observer. 9, 2: 3.1–3.40. Catalogue no. 11-010. Ottawa: Statistics Canada.

Dean, E.R. and M.J. Harper. 2001. “The BLS Productivity Measurement Program.” In *New Developments in Productivity Analysis.* Studies in Income and Wealth. Volume 63. C. Hulten, E.R. Dean and M.J. Harper (eds.). The University of Chicago Press.

Diewert, E. 2004. “Issues in the Measurement of Capital Services, Depreciation, Asset Price Changes and Interest Rates.” The Department of Economics. University of British Columbia.

Durand, R. 1996. “Canadian Input-Output-based Multi-factor Productivity Accounts.” *Economic Systems Research*. 8, 4: 367–389.

Gera, S., W. Gu and F.C. Lee. 1998. *Capital-embodied Technical Change and the Productivity Growth Slowdown in Canada*. Industry Canada Working Paper no. 21. Ottawa: Industry Canada.

Gordon, R.J. 2003. “Exploding Productivity Growth: Context, Causes, and Implications.” *Brookings Papers on Economic Activity.* 2003, 2: 207–298.

Gu, W., M. Kaci, J.-P., Maynard and M. Sillamaa. 2002. “The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth.” Chapter 3 in *Productivity Growth in Canada*. J.R. Baldwin and T.M. Harchaoui (eds.). Catalogue no. 15-204-XIE. Ottawa: Statistics Canada.

Gu, W. and W. Wang. 2004. "Information Technology and Productivity Growth: Evidence from Canadian Industries." In *Economic Growth in Canada and the United States in the Information Age*. D.W. Jorgenson (ed.). Industry Canada Research Monograph. Ottawa: Industry Canada.

Harchaoui, T.M. and F. Tarkhani. 2002. "A Comprehensive Revision of the Capital Input Methodology for Statistics Canada Multifactor Productivity." Chapter 3 in *Productivity Growth in Canada*. J.R. Baldwin and T.M. Harchaoui (eds.). Catalogue no. 15-204. Ottawa: Statistics Canada.

Harchaoui, T.M., F. Tarkhani and B. Khanam. 2004. "Information Technology and Economic Growth in the Canadian and U.S. Private Industries." In *Economic Growth in Canada and the United States in the Information Age*. D.W. Jorgenson (ed.). Industry Canada Research Monograph. Ottawa: Industry Canada.

Ho, M., S. Rao and J. Tang. 2004. "Sources of Output Growth in Canadian and U.S. Industries in the Information Age." In *Economic Growth in Canada and the United States in the Information Age*. D.W. Jorgenson (ed.). Industry Canada Research Monograph. Ottawa: Industry Canada.

Hofmann, N., G. Filoso and M. Schofield. 2005. "The Loss of Dependable Agriculture Land in Canada." *Rural and Small Town Canada Analysis Bulletin*. 6, 1. Catalogue no. 21-006-XIE. Ottawa: Statistics Canada.

Inklaar, R., M.P. Timmer and B. van Ark. 2006. "Productivity and ICT Use in Canada, the U.S., Europe and Australia: Growth and Level Comparisons." Paper presented at the 5th Annual Ottawa Productivity Workshop, May 23-24, 2005.

Jorgenson, D.W. 1966. "The Embodiment Hypothesis." *Journal of Political Economy*. 74, 1: 1–17.

Jorgenson, D.W., F.M. Gollop and B.M. Fraumeni. 1987. "Productivity and U.S. Economic Growth." Cambridge, M.A.: Harvard University Press.

Jorgenson, D.W. and Z. Griliches. 1967. "The Explanation of Productivity Change." *Review of Economic Studies*. 34, 3: 249–283.

Jorgenson, D.W., M. Ho and K. Stiroh. 2005. *Information Technology and the American Growth Resurgence*. The MIT Press.

Keay, I. 2006. "The Persistence of the Old Economy: Canadian Natural Resource Industries, 1970-1999." Department of Economics and School of Environmental Studies, Queens University. Prepared for T.A.R.G.E.T. Outreach Conference, April 13, 2006.

Micro-economic Analysis Division. 2007. *Depreciation Rates for the Productivity Accounts*. Catalogue no. 15-206-XIE2006005. Ottawa: Statistics Canada.

Nordhaus, W.D. 2002. “Productivity Growth and the New Economy.” *Brookings Papers on Economic Activity*. 2: 211–244.

Organization for Economic Co-operation and Development. 1991. Technology and Productivity: the Challenge for Economic Policy. Paris: OECD.

Rao, S., A. Sharpe and J. Smith. 2005. “An Analysis of the Labour Productivity Growth Slowdown in Canada since 2000.” *International Productivity Monitor*. Spring 2005. 10: 3–23.

Robidoux, B. and B.S. Wong. 2003. “Has Trend Productivity Growth Increased in Canada?” *International Productivity Monitor*. Spring 2003, 6: 47–55. Ottawa: Centre for the Study of Living Standards.

Schreyer, P. 2001. OECD Manual-Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth. Paris: Organization for Economic Co-operation and Development.

Sharpe, A. 1998. “Productivity: Key to Economic Success.” Ottawa: Centre for the Study of Living Standards.

Sharpe, A. 2002. “Recent Productivity Developments in the United States and Canada: Implications for the Canada-U.S. Productivity and Income Gaps.” International Productivity Monitor. Spring 2002, 4: 3–14. Ottawa: Centre for the Study of Living Standards.

Sharpe, A. 2003. “Productivity Trends in Natural Resources Industries in Canada.” Research Report 2003-01. Ottawa: Centre for the Study of Living Standards.

Statistics Canada. 2001. Beyond the Information Highway: Networked Canada, Catalogue 56-504-XPE. Ottawa: Statistics Canada.

Stiroh, K. 2002. “Information Technology and the U.S. Productivity Revival: What do the Industry Data Say?” *American Economic Review*. 95, 2: 1559–1576.

van Norden, S. 2005. “Are We There Yet? Looking for Evidence of a New Economy.” HEC Montréal, CIRANO and CIREQ, Montréal: Centre for Research on e-finance.