Economic Growth in Canada and the United States in the Information Age

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Foreword

THE THREE STUDIES PUBLISHED IN THIS MONOGRAPH have employed different concepts and methods for quantifying the contribution of information technologies to economic growth and productivity performance in Canada and the United States. However, their underlying data conform to the international standards recommended by the Organisation for Economic Co-operation and Development. Harchaoui, Tarkhani and Khanam have used an aggregate approach based on national accounts data (final demand gross domestic product), compared to the bottom-up approach by Ho, Rao and Tang and the econometric approach by Gu and Wang. Both papers have employed KLEMS (capital, labour, energy, materials, and services) based industry data. Despite differences in their approaches, the conclusions of the three studies are broadly similar.

The monograph is the result of the collaborative effort of Industry Canada, Statistics Canada and Harvard University. Within Industry Canada, the Policy Sector, the Industry Sector and the Spectrum, Information Technologies and Telecommunications Sector worked together on the project. The conclusions in the monograph reflect the views of the authors, but not necessarily those of Industry Canada, Statistics Canada and the institutions the authors are affiliated with.

Introduction:

Economic Growth in Canada and the United States in the Information Age 1

Dale W. Jorgenson

THE U.S. ECONOMY HAS UNDERGONE A REMARKABLE RESURGENCE since the mid-1990s with accelerating growth in output, labour productivity, and total factor productivity. Jorgenson (2002) has shown that information technology has been an important driving force in the revival of the American economy. Canadian economic performance has also improved dramatically during the late 1990s. However, there are important differences between the Canadian and U.S. economies, especially in the relative importance of industries producing information technology (IT) equipment and software.

The purpose of this volume is to compare and analyze the sources of economic growth in Canada and the United States over the past two decades. This represents a continuation of the research program initially reported in the Industry Canada monograph, *Industry-level Productivity and International Competitiveness between Canada and the United States*, edited by Jorgenson and Lee (2001). The current volume incorporates important new data on productivity in Canada presented in the Statistics Canada monograph, *Productivity Growth in Canada – 2002*, edited by Baldwin and Harchaoui (2003).

In Chapter 2, Harchaoui, Tarkhani, and Khanam provide a detailed comparison of the forces behind the expansion of the private sectors in the Canadian and U.S. economies between 1981 and 2000. For the period as a whole, U.S. economic growth outstripped that in Canada by nearly a full percentage point. The contribution of capital services was the most important source of growth in both countries, while the contribution of labour services was next in importance. Growth of multifactor productivity was slightly negative for the two decades in Canada, but positive and substantial in the United States during the same period.

Both Canada and the United States experienced a slowdown during the period 1988-1995 and a sharp rebound after 1995. The slowdown in Canada before 1995 was much more severe than in the United States. The recovery in Canada was powered by a strong revival of multifactor productivity growth, a surge in the contribution of non-IT capital services, and rapid growth of the contribution of labour services from non-college educated workers. The contribution of investment in IT rose in both countries, but grew far more rapidly in the United States. The contribution of non-IT investment jumped considerably in both countries.

Harchaoui, Tarkhani, and Khanam present a detailed comparison of data for Canada and the United States. The Canadian data for their study are drawn from the Statistics Canada KLEMS (capital, labour, energy, materials, and services) data base, described in greater detail in the monograph by Baldwin and Harchaoui (2003). The U.S. data are taken from Jorgenson, Ho, and Stiroh (forthcoming). The close similarities between data sources and methodology for the two countries make it possible to trace the differences outlined above to differences in the structure and behaviour of the two economies.

In Chapter 3, Gu and Wang analyze the sources of economic growth for 122 Canadian industries, using the most detailed version of the Statistics Canada KLEMS data base. They divide these industries between 33 IT-intensive industries and 89 non-IT intensive industries. The strong revival of multifactor productivity growth after 1995 is the most important source of the Canadian growth revival; they show that this is pervasive among Canadian industries. Capital deepening due to investment in IT is relatively unimportant in the Canadian revival by contrast with the United States.

The surge in multifactor productivity growth in Canada after 1995 was strongest in IT-intensive industries. Gu and Wang attribute this to IT-induced organizational innovation and network effects. They find that IT-intensive industries made relatively little contribution to multifactor productivity growth before 1995. They also find that industries that had a larger share of university-educated workers made larger productivity gains after 1995. A possible explanation is that these workers are complementary to investments in IT equipment and software.

The Canadian KLEMS data base employed by Gu and Wang incorporates the results of recent research on the impact of changes in the composition of the Canadian labour force by age, sex, and education by Gu, Kaci, Maynard, and Sillamaa (2003). It also includes new estimates of capital inputs for Canadian industries by Harchaoui and Tarkhani (2003). These estimates reflect differences in the behaviour of investment goods prices, for example, between IT and non-IT investment goods. The estimates also incorporate differences in service lives, depreciation rates, and tax treatments among different types of assets.

In Chapter 4, Ho, Rao, and Tang compare the sources of output growth for 34 industries in Canada and the United States. They show that IT-producing industries were the sources of much of the acceleration in multifactor productivity growth in the United States after 1995. The proportion of university-educated workers in the employed labour force is much smaller in Canada than the United States. Growth in the contribution of these workers to the growth of labour input was another important source of the U.S. growth resurgence in the late 1990s.

In order to isolate the differences in the behaviour of individual industries in Canada and the United States, Ho, Rao, and Tang have separated the 34 industries into three groups — IT-producing industries, IT-intensive industries, and industries that are not IT-intensive. They classify 3 industries — computers; communication and electronic equipment; and communications — as IT-producing industries, 9 other industries as IT-intensive industries, and the remaining 22 industries as non-IT-intensive industries.

The IT-producing industries grew at phenomenal rates in both Canada and the United States during the period 1981-2000, far exceeding the average of other industries. These industries contributed substantially more to U.S. than Canadian economic growth because of their greater relative importance in the U.S. economy. All three groups of industries contributed to the acceleration of economic growth in Canada and the United States after 1995. However, most of the acceleration in Canada was due to the non-IT-intensive industries, while in the United States, the acceleration took place mainly in the IT-intensive industries.

The results of this study are critically important in evaluating the prospects for future growth in Canada and the United States. Jorgenson, Ho, and Stiroh (2003) have shown that the rapid pace of economic growth in the United States during the late 1990s was not sustainable. This involved an expansion of hours worked at twice the rate of the growth of the working age population. The unemployment rate plummeted and the rate of participation in the labour force increased. Nonetheless, prospects for potential growth at sustainable rates have improved.

Jorgenson, Ho, and Stiroh (2003) have undertaken a similar, but less detailed, analysis of prospects for future Canadian economic growth. They project more rapid growth for the Canadian labour force than the United States. Labour quality, defined as labour input per hour worked, is also projected to grow more rapidly in Canada than in the United States as Canadian levels of educational attainment approach U.S. levels. However, multifactor productivity growth is projected to be slower in Canada than in the United States, mainly due to the greater relative importance of IT-producing industries in the United States.

Growth rates for the two countries are gradually converging, but the growth potential for Canada remains about half a percentage point below the United States. In both countries, projections of future growth are characterized by substantial uncertainties. For the United States, these arise from the role of IT investment and the future growth of multifactor productivity in the IT-producing industries. For Canada, the growth rate of multifactor productivity outside these industries and the rate at which IT equipment and software can be substituted for other types of capital inputs are associated with important uncertainties.

Bibliography

Baldwin, J.R., and T.M. Harchaoui, eds. *Productivity Growth in Canada – 2002*. Ottawa: Statistics Canada Catalogue No. 15-204-XPE, 2003.

Gu, W., M. Kaci, J.-P. Maynard, and M. Sillamaa. "The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin, and T.M. Harchaoui. Ottawa: Statistics Canada Catalogue No. 15-204-XPE, 2003.

Harchaoui T.M., and F. Tarkhani. "A Comprehensive Revision of the Capital Input Methodology for Statistics Canada Multifactor Productivity." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin, and T.M. Harchaoui. Ottawa: Statistics Canada Catalogue No. 15-204-XPE, 2003.

Jorgenson, D.W., ed. "Information Technology and the U.S. Economy." In *Economic Growth in the Information Age*. Cambridge: MIT Press, 2002, pp. 1-42.

Jorgenson, D.W., M.S. Ho, and K.J. Stiroh. "Growth in U.S. Industries and Investments in Information Technology and Higher Education." In *Measuring Capital in the New Economy*. Edited by C. Corrado, J.C. Haltiwanger, and D. Sichel. Chicago: University of Chicago Press. Forthcoming.

———. "Lessons for Canada from the U.S. Growth Resurgence." *International Productivity Monitor* 6 (Spring 2003): pp. 3-18.

Jorgenson, D.W., and F.C. Lee, eds. *Industry-level Productivity and International Competitiveness between Canada and the United States*. Research Monograph. Ottawa: Industry Canada, 2001.

Information Technology and Economic Growth in the Canadian and U.S. Private Economies 2

Tarek M. Harchaoui, Faouzi Tarkhani & Bilkis Khanam

Abstract

THIS STUDY USES NEW DATA at both the aggregate and industry levels to shed additional evidence on the sources of growth for labour productivity and economic growth in the Canadian and U.S. private economies over the period 1981-2000. The principal innovation is the incorporation of the service flows of consumer durables and housing in the aggregate production framework. Another feature of this study is the use of new industry data and the distinction between university and non-university workers to capture the extent to which investments in higher education and information technology have contributed to economic growth and productivity performance. The new results confirm the basic story laid out in our earlier work—while information technology accounted for much of the U.S. productivity revival, it played a modest role in Canada, thereby suggesting different forces at work in the two countries.

Introduction

CONSIDERABLE UNCERTAINTY HANGS OVER the world economy at present. While the future remains uncertain, it is clear that Canada and the United States have undergone a remarkable transformation in recent years, with growth in output, labour productivity, and multifactor productivity all accelerating since the mid-1990s. This growth resurgence has led to a widening debate about the sources of this growth and whether profound changes have taken place in the structure of the two economies.

The conjunction of an information technology boom and an acceleration in productivity growth in the United States in the second half of the 1990s excited talk of a *new economy*, though some enthusiasm for the concept has subsided in the wake of the *tech wreck*. But a more sober new economy discussion continues.

The focus is on the link between information technology and its effect on economic growth and productivity growth.[1]

There are many examples of cutting-edge businesses in the United States, such as IBM and Wal-Mart, that produce and use information technology effectively. While it is often argued that Canada is not a major producer of information technology, research conducted in Canada shows that information technology contributed substantially to the growth of gross domestic product (GDP), capital formation and productivity.[2] It is clear that the impact of investment in information technology on both the Canadian and U.S. economies has been substantial. But how and to what degree do the effects of this investment differ between the two countries?

In order to compare the relationships between investment in information technology, economic growth and productivity performance in Canada and the United States, it is essential to eliminate the differences in measurement of output and inputs in the official statistics. In keeping with best practice, recent Canada-U.S. comparisons produced by Statistics Canada have employed concepts and methods that accord with the Organisation for Economic Co-operation and Development (OECD) productivity manual (OECD 2001).[3]

Harchaoui, et al. (2002) outlined that the late 1990s were exceptional in comparison with the growth experience of the Canadian and the U.S. business sectors over the past quarter century as a whole. Although growth rates have not returned to those of the golden age of the two economies in the early 1960s, the data nonetheless clearly revealed a remarkable transformation. After more than 20 years of sluggish multifactor productivity growth, 4 of the 5 years ending in 2000 saw growth rates near 1 percent. This acceleration of multifactor productivity growth was one of the most remarkable features of the data, suggesting massive improvements in technology and increases in the efficiency of production.

Harchaoui and Tarkhani (2004a) refined and extended that analysis by using an augmented aggregate growth accounting framework fully integrated to a sectoral model to trace the various channels through which information technology operates. Their results suggest that while information technology is indeed the story in the U.S. productivity revival, it is only part of it in the Canadian context. The labour productivity revival is primarily attributable to information technology capital deepening and multifactor productivity gains of information technology-producing industries. The Canadian evidence points towards the importance of multifactor productivity gains in information technology-using industries as a major source of productivity acceleration.

To assess the robustness of our earlier work, this study extends our initial framework and exploits a new data set on the sources of growth for Canada and the United States over the 1981-2000 period.[4] We extend our contribution in the following directions.

First, we extend our coverage from the business sector to the private domestic economy. This notion comprises the business sector itself and owner-occupied housing, thereby improving our coverage and making it more consistent with the System of National Accounts' domain of definition.[5]

Second, we measure the service flow from the stock of durables in lieu of expenditure.[6] The purchase of consumer durables is recorded as capital investment and the service flow from the stock of durables as consumption, since the latter represents the portion actually consumed in a given period. This approach is appealing for two reasons: a) it makes the treatment of consumer durables similar to that used in the System of National Accounts to account for rents of owner-occupied dwellings, and b) it also makes the treatment of consumer durables symmetric to the one already in place in the productivity accounts for the measurement of producers durable goods.

Third, on the labour side, university-educated workers are often identified as *knowledge workers* who make use of information technology, so we have divided labour input between university and non-university workers to capture the extent to which investments in higher education and information technology have contributed to economic growth and productivity performance in Canada and the United States. While the growth of labour input from university-educated workers has predominated over growth from non-university workers for the period 1981-2000, the contribution of non-university workers is also important. The substitution of university-educated workers for non-university workers has been an important mechanism for restructuring the Canadian and U.S. work forces. This reflects the increased role of knowledge workers in many industries, especially those that have invested large amounts in information technology equipment.

Fourth, an important feature of our methodology is the explicit role provided for intermediate inputs. Consider, for example, the output of the semiconductor industry. Much of this output is invisible at the aggregate level, since semiconductor products are mainly inputs into other industries rather than deliveries to final demand as consumption and investment goods. Semiconductor inputs, however, play a key role in the improvements in the quality and performance of computers, communications equipment, instruments, and a host of other products (see Jorgenson 2001).

More specifically, semiconductors are an output of the electronic components industry, but appear as intermediate inputs into computers, communications equipment, and other industries. Price declines resulting from improvements in semiconductor technology are reflected in the large contributions of intermediate inputs in the industries that consume semiconductors. By accurately accounting for intermediate inputs through the use of inter-industry transactions tables, we can allocate Canadian and U.S. economic growth to its sources in individual industries.

The results obtained in this study continue to support the basic story laid out in our earlier work; namely, the data still show a substantial pickup in the U.S. labour productivity growth in the late 1990s and indicate that efficiency gains associated with the production of information technology were central factors in that resurgence. This contrasts with the Canadian evidence where the bulk of the increase of labour productivity was attributable to efficiency gains outside the information technology-producing industries. Interestingly, the Canadian story remains intact even with the adoption of international harmonized prices for information technology-producing industries.

This *top down* approach, which tries to allocate final demand GDP growth to information technology-producing industries and information technology-using industries, is complemented by the *bottom up* analysis employed by Ho, Rao and Tang, in this volume. The latter uses detailed industry-level data to trace the sources of Canada-U.S. economic growth to their industry origins, to isolate and analyze the industries that use information technology, and to ascertain the relative importance of productivity growth and factor accumulation. Their results, consistent with ours, have shown that information technology is indeed the story for the U.S. productivity revival, compared to Canada, where it has made a modest contribution. Information technology-using and non-using industries generated all of the multifactor productivity revival of the Canadian business sector. Using a parametric framework for detailed Canadian industry data, Gu and Wang in this volume have attributed Canada's productivity surge to information technology-induced organizational changes and possible spillover effects.

The remainder of this study is as follows: The next section extends the coverage of Harchaoui and Tarkhani (2004a) to incorporate the service flows of durables and housing. We employ a methodology developed by Jorgenson and Stiroh (2000) and summarize it briefly. The following section presents our results of the trend growth of output, inputs and productivity for Canada and the United States over the 1981-2000 period. The last section concludes the study.

The Extended Accounting Framework

Set Up

OUR ANALYSIS OF THE SOURCES OF ECONOMIC GROWTH employs an aggregate production possibility frontier to examine how capital input, labour input, and technology, are used to create the private sector output of consumption commodities, investment goods, and net exports. It captures substitution between investment and consumption goods on the output side and between capital and labour inputs on the input side.

This aggregate framework serves as the basis for this study. Recent work that implemented this approach includes Jorgenson and Stiroh (2000) and Jorgenson (2001) for the U.S. economy; Jorgenson and Yip (2001) and Dougherty and Jorgenson (1997) for international comparisons, and Harchaoui and Tarkhani (2004a) for a Canada-U.S. comparison of economic growth and productivity performance.

Following Christensen and Jorgenson (1973), this study introduces several changes to the production framework that was employed in our previous work. Since the household sector is included in the production sector, the capital service flow from consumer durables must be treated as both an output and input of households.

The imputed capital services from owner-occupied housing are included in the Canadian System of National Accounts (CSNA) and U.S. National Income and Product Accounts (NIPA) but not in the productivity accounts of the two countries. In this study, we make these two sets of accounts consistent as far as the treatment of housing is concerned. The flows of capital services resulting from investment in housing by owner-occupiers and investment in structures by households are added to the notion of the business sector used by the productivity accounts of the two countries.

In addition, we treat other types of consumer durables, including information technology assets, in the same way as housing. The idea of capitalizing consumer durables in the CSNA and the NIPA has been discussed for many years.[7] Currently expenditures for consumer durables are treated as consumption expenditures rather than investment expenditures. Capitalizing consumer durables would reallocate expenditures for them from personal consumption expenditures to gross private domestic investment and would increase GDP by the amount of services they provide equal to the rental value of the durables.

We treat housing and consumer durables consistently and include both of the two assets in the capital input, and the flow of services from the installed stock of each in consumption in the aggregate production function. The purchase of new housing and consumer durables are treated as investment.

The Production Possibility Frontier

In the production possibility frontier, output (Y) consists of consumption goods (C), investment goods (I), and other components (O). These outputs are produced from aggregate input (X), consisting of capital services (K) and labour services (L). These outputs can be further decomposed into information technology output (Y_{IT}) and non-information technology output (Y_{NIT}). Information technology outputs include information technology investment goods—computer hardware (I_C), computer software (I_S), communications equipment (I_M) — information technology capital services to households (C_{IT}) and other information technology components (O_{IT}) (information technology services, net exports, etc.). This is also done for the components of the aggregate non-information technology output (Y_{NIT}). Likewise, capital services can be decomposed into the capital service flows from hardware (K_C), software (K_S), communications equipment (K_M), and all other capital services (K_o).[8] A similar decomposition was performed for labour input between university (L_U) and non-university (L_{NU}) workers. The input function (X) is augmented by multifactor productivity (A).

The production possibility frontier can be represented as:

$$Y[Y_{IT}(I_{IT},C_{IT},O_{IT}),Y_{NIT}(I_{NIT},C_{NIT},O_{NIT})]= \\ A\cdot X[K_{IT}(t),K_{OME}(t),K_S(t),L_U(t),L_{NU}(t)]. \quad (1)$$

Under the standard assumptions of competitive product and factor markets, and constant returns to scale, Equation (1) can be transformed into an equation that accounts for the sources of economic growth:

$$\bar{w}_{Y_{IT}}\Delta\ln Y_{IT}+\bar{w}_{Y_{NIT}}\Delta\ln Y_{NIT}=\bar{v}_{K_{IT}}\Delta\ln K_{IT}+\bar{v}_{K_{OME}}\Delta\ln K_{OME}+\bar{v}_{K_S}\Delta\ln K_S \\ +\bar{v}_{L_U}\Delta\ln L_U+\bar{v}_{L_{NU}}\Delta\ln L_{NU}+\Delta\ln A, \quad (2)$$

where $\Delta x \equiv x_t - x_{t-1}$. $\bar{w}$ denotes the average output shares and $\bar{v}$ the average input shares of the subscripted variables; the shares are averaged over period t and t–1, and $\bar{w}_{Y_{IT}}+\bar{w}_{Y_{NIT}}=\bar{v}_{K_{IT}}+\bar{v}_{K_{OME}}+\bar{v}_{K_S}+\bar{v}_{L_U}+\bar{v}_{L_{NU}}=1.0$. We refer to the share-weighted growth rates in equation (2) as the contributions of the inputs and outputs.

Labour productivity is defined as the ratio of output to hours worked, so that $LP\equiv y=\frac{Y}{H}$, where the lower-case variable (y) denotes output (Y) per hour (H). Equation (2) can be rewritten in per hour terms as:

$$\Delta\ln y=\bar{v}_{K_{NIT}}\Delta\ln k_{NIT}+\bar{v}_{K_{IT}}\Delta\ln k_{IT}+\bar{v}_{L_U}\Delta\ln\ell_U+\bar{v}_{L_{NU}}\Delta\ln\ell_{NU} \\ +\left(\bar{v}_{L_U}\Delta\ln h_U+\bar{v}_{L_{NU}}\Delta\ln h_{NU}\right)+\Delta\ln A_t, \quad (3)$$

where $\bar{v}_{K_{IT}}=v_{K_C}+v_{K_S}+v_{K_T}$ and $\bar{v}_{K_{NIT}}=v_{K_{OME}}+v_{K_S}$; $\Delta\ln k_{IT}$ and $\Delta\ln k_{NIT}$ are, respectively, the growth of information technology and non-information technology capital services per hour (capital deepening); $\Delta\ln\ell_u$ and $\Delta\ln\ell_{NU}$ are, respectively, the growth of labour quality of university-workers and non-university workers; and $\Delta\ln h_U$ and $\Delta\ln h_{NU}$ are, respectively, the growth of hours of university-workers and non-university workers per total hours worked.

Equation (3) decomposes labour productivity growth into three sources. The first is capital deepening, defined as the contribution of capital services per hour, which is decomposed into non-information technology and information technology components. The interpretation of capital deepening is that additional capital per hour makes workers more productive in proportion to the capital share. The third and fourth terms capture labour quality improvement, defined as the contribution of labour input per hour worked, for university and non-university workers, respectively. This reflects changes in the composition of the workforce and raises labour productivity in proportion to the labour share of each category of workers. The fifth term, hours reallocation, reflects compositional shifts between university and non-university workers. The last term is multifactor productivity growth, which raises labour productivity growth point-for-point.

Data

We briefly summarize the data required to implement Equations (1) to (3) here. More detailed descriptions are available in Ho and Jorgenson (1999) and the appendices of Jorgenson and Stiroh (2000) and Jorgenson, Ho, and Stiroh (forthcoming) for the U.S. data, and Baldwin and Harchaoui (2003) for the Canadian productivity accounts.

Output

The aggregate data are based on the most recent benchmark revision of the Canadian and U.S. national accounts, updated through 2000. These data are based on Income and Expenditures Accounts (IEAs) and the NIPAs maintained, respectively, by Statistics Canada and the U.S. Bureau of Economic Analysis. These accounts provide measures of final demand GDP in both current and chained dollars. The framework developed in this study calls for a broader treatment of output than the official ones used in national accounts and productivity programs of the two countries. First, the services of owner-occupied housing and structures utilized by households are included in the GDP, thereby making the coverage of the productivity accounts in line with that of national accounts of the two countries. Second, consumer durable goods are treated symmetrically with investment in housing, since both are long-lived assets that are accumulated and provide a flow of services over their lifetimes. We use a rental price to impute a flow of consumer durables services included in both consumption and capital input. The value of the service flow of housing are imputed from rental values available from the IEAs and the NIPAs.[9]

Table 1 provides information on the value of outputs and inputs for 1981 and 2000 and Tables 2a and 2b report the average annual growth rates of quantity and prices for these outputs and inputs, respectively, for Canada and the United States for the following periods: 1981-2000, 1981-88, 1988-2000, 1988-95 and 1995-2000. While these time periods are conventional for the Canada-U.S. comparison in terms of multifactor productivity growth, a word about the choice of the periods is useful at this point. The year 1981 is the first year in our KLEMS (capital, labour, energy, materials, and services) data set for which the data are comparable.[10] The years 1988 and 2000 are, respectively, the first and the second peak of the cycle in the period we cover; the year 1995 corresponds to a surge in economic growth.

The Canadian and U.S. concepts of output are similar, but not identical, to the official concept of gross domestic product. Our output measure is somewhat broader than the one used in the official Canada-U.S. productivity statistics, published by Statistics Canada (2002) and the Bureau of Labor Statistics (BLS) (2002), and employed by Harchaoui et al. (2002) and Harchaoui and Tarkhani (2004a). Both measures include final outputs purchased by households, businesses, and the rest of the world. The output measures in Table 1, unlike the one used in our previous work, includes imputations for the service flows from housing and durable goods, including information technology products, employed in the household sector.

The imputations for services of information technology assets are based on the cost of capital for information technology described in more detail below. The cost of capital is multiplied by the nominal value of information technology capital stock to obtain the imputed service flow from information technology assets. In the business sector, this accrues as capital income to the firms that employ these products as inputs. In the household sector, the flow of capital income must be imputed. This same type of imputation is used for housing in the IEAs in Canada and the NIPAs in the United States. The rental value of renter-occupied housing accrues to real estate firms as capital income, while the rental value of owner-occupied housing is imputed to households.

Output includes investment goods in the form of computers, software, communication equipment, and non-information investment goods. It also includes outputs and non-information technology consumption goods and services, imputed information technology capital service flows from households and net exports. Canadian current dollar GDP was $978.4 billion in 2000 ($9.4 trillion for the United States), including imputations, and real output growth averaged 2.7 percent (3.7 percent for the United States) for the period 1981-2000 (see Table 1 and Tables 2a and 2b). These magnitudes can be compared to the current dollar value of $774 billion in 2000 for Canada ($7.7 trillion in 2000 for the United States) and the average real growth rate of 3.1 percent for period 1981-2000 for the official Canadian business sector GDP (3.9 percent for the United States).

Table 1

Information Technology Outputs and Inputs ($ billion)

	Canada		United States	
	1981	**2000**	**1981**	**2000**
Gross Domestic Product (GDP)	326.6	978.4	2,885.9	9,350.7
Information Technology GDP	6.9	43.3	109.0	616.6
Computer and Software Consumption	0.2	3.3	0.4	34.3
Computer Investment	2.6	12.4	17.1	109.3
Software Investment	1.1	15.4	16.1	198.2
Communication Investment	2.1	7.0	37.2	135.6
Consumer Durable Services	0.2	3.6	0.3	42.2
Communication Services	3.0	11.3	30.9	131.3
Other	–2.2	–9.8	–3.8	–12.5
Non-information Technology GDP	319.7	935.1	2,776.9	8,734.1
Housing Services	31.2	109.0	131.3	387.2
Housing Investment	21.5	48.8	118.9	416.9
Other	267.0	777.3	2,526.7	7,930.0
Capital Compensation	168.4	517.3	1,110.1	3,636.7
Information technology	5.2	34.9	50.8	424.9
Computers	2.3	13.0	14.9	111.0
Communication	2.1	7.1	12.2	160.8
Software	0.6	10.9	23.3	110.9
Consumer Durable Services	0.2	3.9	0.3	42.2
Non-information Technology	163.2	482.3	1,059.3	3,211.8
Other Machinery and Equipment	25.2	82.4	207.0	700.0
Other Durables	35.8	88.9	273.5	905.7
Structures	102.2	311.1	578.8	1,606.1
Housing	40.0	140.4	203.0	594.1
Other	62.2	158.6	375.8	1,012.1
Labour Compensation	158.2	461.1	1,645.8	5,112.9
University-educated Workers	17.3	115.6	381.2	1,989.5
Non-university-educated Workers	140.9	345.5	1,264.5	3,123.4

The most striking feature of the data in Tables 2a and 2b is the rapid price decline for computer investment, 15.3 percent per year for Canada from 1981 to 2000 (15.5 percent for the United States). At less than 3 percent per year during this period in both Canada and the United States, the price of software declined less rapidly than that of computers (–2.11 percent for Canada and –0.7 percent for the United States). In contrast, the price of telecommunication equipment behaved slightly differently between Canada and the United States (a 0.6 percent increase in Canada, compared to a 0.1 percent decline for the United States), while the service flows of consumers information technology durable goods show less rapid price declines in Canada compared to the United States (–9.3 percent compared to –19.4 percent).

Business investments in computers, software, and communication equipment are the largest categories of information technology spending. Households have also spent sizable amounts on computers, software, communication equipment and the services of information technology.

Figures 1a and 1b show that the output of information technology equipment (computers, software and communication investments) is the largest information technology category as a share of GDP, followed by the outputs of communication services and the services flows of durables in both Canada and the United States. In contrast, the share of information technology consumption remained fairly small over the 1981-2000 period.

Capital Services

This section presents the estimates of capital services for the Canadian and U.S. private economies for the period 1981 to 2000. These begin with IEA and NIPA investment data; the perpetual inventory method generates estimates of capital stocks and these are aggregated, using service prices as weights. This approach, originated by Jorgenson and Griliches (1967), is based on the identification of service prices with marginal products of different types of capital. The service price estimates incorporate the cost of capital, an annualization factor that transforms the price of an asset into the price of the corresponding capital input. The cost of capital includes the nominal rate of return, the rate of depreciation, and the rate of capital loss due to declining prices.

Table 2a

Growth Rates of Outputs and Inputs, Canada (average annual percentage rates of growth)

	1981-2000		1981-88		1988-2000		1988-95		1995-2000	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
Gross Domestic Product (GDP)	3.2	2.7	4.6	3.2	2.4	2.4	2.9	0.9	1.7	4.5
Information Technology-GDP	–3.7	14.4	–1.7	12.2	–4.8	15.6	–5.1	11.7	–4.3	21.4
Computers and Software Consumption	–8.6	26.5	–11.3	42.0	–7.0	18.2	–4.1	17.5	–10.8	19.1
Computers Investment	–15.3	28.3	–16.1	28.3	–14.8	28.4	–13.5	21.5	–16.7	38.7
Software Investment	–2.1	17.5	–0.9	21.4	–2.8	15.3	–4.2	14.7	–1.0	16.3
Communication Investment	0.6	5.9	4.1	3.2	–1.4	7.6	–2.3	5.5	–0.1	10.5
Consumer Durable Services	–9.3	28.5	–13.2	44.2	–7.0	20.1	–4.5	21.1	–10.5	18.7
Communication Services	1.1	6.2	2.4	6.0	0.3	6.2	–0.6	5.6	1.5	7.2
Other	–7.2	16.6	–10.1	25.9	–5.6	11.5	–4.1	14.2	–7.6	7.8
Non-information Technology-GDP	3.4	2.4	4.7	3.0	2.6	2.0	3.1	0.6	1.9	3.9
Housing Services	3.3	3.4	5.7	3.8	2.0	3.1	3.2	3.3	0.2	2.9
Housing Investment	3.1	1.2	5.3	4.8	1.9	–0.8	2.2	–4.4	1.5	4.5
Other	3.4	2.3	4.5	2.8	2.7	2.0	3.2	0.6	2.2	4.0
Capital Services	3.4	2.6	5.2	2.9	2.4	2.4	2.3	1.8	2.5	3.2
Information Technology	–7.0	18.9	–5.1	20.1	–8.1	18.2	–8.4	15.6	–7.8	22.0
Computers	–15.2	29.1	–14.9	29.4	–15.4	28.9	–14.5	21.8	–16.6	39.5
Communication	1.2	5.4	7.2	2.8	–2.1	7.0	–4.8	6.4	1.8	7.9
Software	–2.1	18.9	2.4	24.5	–4.6	15.7	–6.0	16.0	–2.6	15.3
Consumer Durable Services	–9.3	28.5	–13.0	44.2	–7.1	20.1	–4.8	21.1	–10.2	18.7

Table 2a (cont'd)

Growth Rates of Outputs and Inputs, Canada (average annual percentage rates of growth)

	1981-2000		1981-88		1988-2000		1988-95		1995-2000	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
Non-information Technology	3.8	2.0	4.9	3.0	3.2	1.4	2.9	1.1	3.6	1.8
Other Machinery and Equipment	4.3	2.0	8.6	1.5	2.0	2.3	2.0	1.0	1.9	4.3
Other Durables	3.7	1.1	3.9	3.3	3.6	–0.1	4.8	–1.0	2.0	1.2
Structures	3.7	2.2	4.3	3.3	3.4	1.6	2.7	1.8	4.5	1.3
Housing	3.8	2.9	4.0	5.3	3.7	1.6	3.3	2.4	4.2	0.5
Other	3.8	1.6	4.7	1.8	3.2	1.6	2.2	1.3	4.6	2.0
Labour Services	3.4	2.4	4.9	2.6	2.4	2.2	2.2	1.2	2.8	3.8
University-educated Workers	4.4	5.9	4.6	6.5	4.3	5.6	5.0	5.1	3.4	6.3
Non-university-educated Workers	3.1	1.6	5.0	2.0	2.1	1.4	1.7	0.3	2.6	3.1
					Addendum					
Hours at Work	1.6		2.0		1.5		0.3		3.1	
University-educated Workers	5.5		6.0		5.2		4.6		6.0	
Non-university-educated Workers	1.1		1.6		0.9		-0.3		2.6	

Table 2b

Growth Rates of Outputs and Inputs, United States (average annual percentage rates of growth)

	1981-2000		1981-88		1988-2000		1988-95		1995-2000	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
Gross Domestic Product (GDP)	2.6	3.7	3.7	3.8	1.9	3.7	2.5	2.9	1.1	4.8
Information Technology-GDP	-4.9	15.2	-2.6	13.2	-6.3	16.5	-4.3	11.9	-9.0	23.2
Computers and Software Consumption	-19.8	57.7	-16.3	83.9	-21.8	44.1	-17.2	38.2	-27.8	52.8
Computers Investment	-15.5	30.4	-13.9	30.2	-16.4	30.6	-12.0	22.6	-22.1	42.6
Software Investment	-0.7	14.9	0.4	15.7	-1.3	14.4	-1.5	12.4	-1.0	17.3
Communication Investment	-0.1	7.2	1.6	4.4	-1.1	8.9	-0.4	3.8	-2.2	16.3
Consumer Durable Services	-19.4	60.4	-17.8	91.9	-20.4	44.4	-13.9	38.4	-28.7	53.3
Communication Services	1.1	6.8	3.6	4.6	-0.4	8.0	0.4	6.7	-1.5	10.0
Other	3.0	3.2	4.0	3.4	2.4	3.0	2.9	2.5	1.7	3.7
Non-Information Technology-GDP	2.7	3.1	7.8	3.3	-0.2	3.0	0.5	2.8	-1.2	3.3
Housing Services	3.3	3.4	4.0	5.6	3.0	2.1	2.8	0.1	3.3	5.0
Housing Investment	3.0	3.1	3.8	3.3	2.5	3.1	3.0	2.6	1.8	3.7
Other	2.1	2.3	3.5	3.1	2.1	2.4	1.7	2.0	1.9	2.2
Capital Services	2.1	4.2	4.3	4.3	0.9	4.2	1.5	3.1	-0.1	5.8
Information Technology	-6.2	19.3	-5.1	22.1	-6.9	17.6	-2.8	12.6	-12.4	25.1
Computers	-13.2	28.1	-12.0	34.0	-13.9	24.8	-8.0	13.8	-21.5	41.8
Communication	-0.8	15.4	1.0	15.7	-1.7	15.2	-1.4	14.3	-2.3	16.4
Software	1.6	6.8	3.5	8.1	0.5	6.1	4.1	4.4	-4.3	8.5
Consumer Durable Services	-19.4	60.4	-17.8	91.9	-20.4	44.4	-13.9	38.4	-28.7	53.3

Table 2b (cont'd)

Growth Rates of Outputs and Inputs, United States (average annual percentage rates of growth)

	1981-2000		1981-88		1988-2000		1988-95		1995-2000	
	Price	**Quantity**	**Price**	**Quantity**	**Price**	**Quantity**	**Price**	**Quantity**	**Price**	**Quantity**
Non-information Technology	3.0	2.9	5.0	3.3	1.9	2.7	2.0	2.1	1.7	3.4
Other Machinery and Equipment	4.6	1.9	6.3	1.4	3.6	2.2	4.3	1.5	2.8	3.1
Other Durables	2.1	4.3	4.0	5.2	1.0	3.9	1.4	2.8	0.4	5.3
Structures	2.9	2.5	5.0	3.0	1.7	2.2	1.5	2.0	2.0	2.6
Housing	3.2	2.5	7.2	2.8	0.9	2.4	1.4	2.2	0.3	2.7
Other	2.8	2.5	3.7	3.2	2.2	2.1	1.6	1.9	3.0	2.5
Labour Services	3.9	2.2	4.8	2.3	3.4	2.1	3.3	1.8	3.4	2.5
University-educated Workers	5.1	3.8	6.6	5.1	4.2	3.1	4.1	2.7	4.4	3.5
Non-university Educated Workers	3.4	1.4	4.2	1.3	2.9	1.6	2.9	1.3	2.9	1.9
					Addendum					
Hours at Work	1.9		2.0		1.8		1.4		2.3	
University-educated Workers	4.0		5.5		3.1		2.7		3.6	
Non-university-educated Workers	1.3		1.2		1.3		1.0		1.8	

Figure 1a

Output Shares of Information Technology by Type, Canada (percent of current dollar gross domestic product)

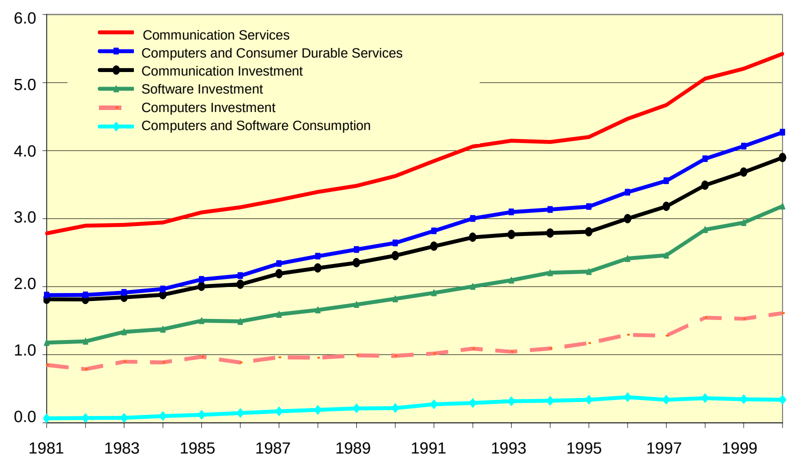
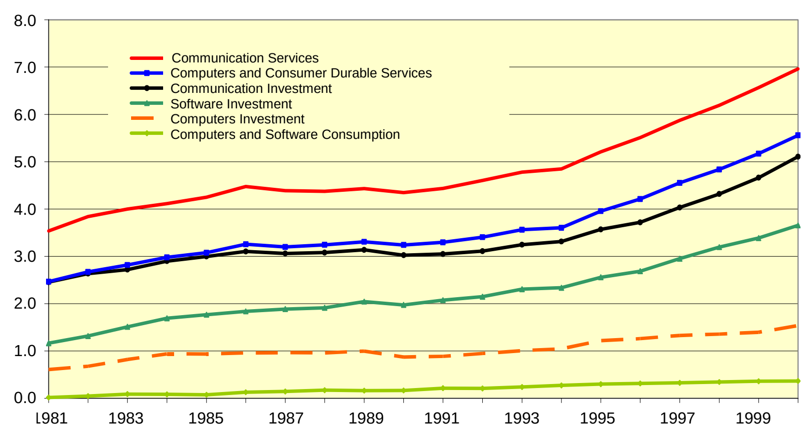


Figure 1b

Output Shares of Information Technology by Type, United States (percent of current dollar gross domestic product)



For our aggregate framework, we require an aggregate measure of capital services across all types of reproducible fixed assets, consumer durable assets, inventories, and land. We employ quantity indexes of these assets to generate aggregate capital services, capital stock, and investment series.

The definition of capital includes all tangible assets in the Canadian and U.S. private economies, equipment and structures, as well as consumer and government durables, land, and inventories. For the purpose of this Canada-U.S. comparison, Canadian (U.S.) national accounts data were reclassified into 24 (52) non-residential assets, 4 (5) residential assets, and 13 (13) consumer durable assets. For each asset, we created an investment series in current and chained dollars. Although the implicit prices of some assets, particularly those associated with information technology, behave differently in the two countries, the differences do not impact significantly on the order of magnitude of the contributions of information technology to output, capital inputs and productivity growth at the aggregate level (see Harchaoui and Tarkhani, 2004a).

Capital stocks were then estimated using the perpetual inventory method and a geometric depreciation rate. Canadian depreciation rates are estimated econometrically using the age-price profile based on a sample of 30,000 observations of non-residential used assets dating from 1987 to 1995 maintained by Statistics Canada (Harchaoui and Tarkhani, 2003). The U.S. depreciation rates are based on the Bureau of Economic Analysis (BEA) estimates constructed during the 1980s (see Fraumeni, 1997), with the exception of automobiles, software and computers derived by Dale Jorgenson and his associates (see Jorgenson and Stiroh, 2000, p. 203).

Generally, for similar information technology assets, Canada’s depreciation rates are higher that their U.S. counterparts. In a capital stock universe, this may lead to a lower growth of capital stock for Canada, compared to the United States. While depreciation rates are higher in Canada, information technology price declines tend to be lower. In the capital services framework, for a given rate of return, higher depreciation rates in favour of Canada are outweighed by more rapid price declines for the United States, with the result that the two measurement differences tend to cancel out. This implies that under the capital services framework, cross country measurement differences may have a modest impact on productivity performance.

Business information technology investments, as well as purchases of computers, software, and communications equipment by households and governments, have grown spectacularly in recent years, but remain relatively small (Table 1). In Canada, the stocks of all information technology assets combined accounted for only 3.0 percent of domestic tangible capital stock in 2000, up from 1.5 percent in 1981 (respectively 4.8 percent and 2.5 percent for the United States).

The capital service flows from durable goods employed by households and governments enter measures of both output and input. A steadily rising proportion of these service flows are associated with investments in information technology. Investments in information technology by business, household, and government sectors must be included in the GDP, along with household and government information technology capital services, in order to capture the full impact of information technology on the Canadian and U.S. private economies.

Figures 2a and 2b give the information technology capital service flows as a share of gross domestic capital income. While information technology assets are only 3.0 percent of total capital in 2000 (4.8 percent for the United States), these figures show that the information technology service shares, or the cost of capital shares, of these assets are twice as high as the corresponding asset shares. In 2000, it was 6.8 percent in Canada (10.4 percent for the United States), more than double what it was in 1981 (respectively 3.1 percent and 4.3 percent for Canada and the United States). This reflects the rapid price declines and high depreciation rates that enter into the rental prices for information technology.

Figures 2a and 2b also depict the rapid increase in the importance of information technology services, reflecting the accelerating pace of information technology price declines. During the 1995-2000 period, the capital service price for computers fell 16.6 percent per year in Canada (21.5 percent for the United States), compared to an increase of 39.5 percent in capital input for computers (41.8 percent for the United States) (see Tables 2a and 2b). As a consequence, the value of computer services grew substantially. However, the cost of capital share of computers was only 2.5 percent of gross domestic income in 2000 in Canada (2.7 percent for the United States), up from 1.6 percent in 1995 (2.1 percent for the United States) (see Figures 2a and 2b).

Figure 2a

Input Shares of Information Technology by Type, Canada
(percent of current gross domestic capital income)

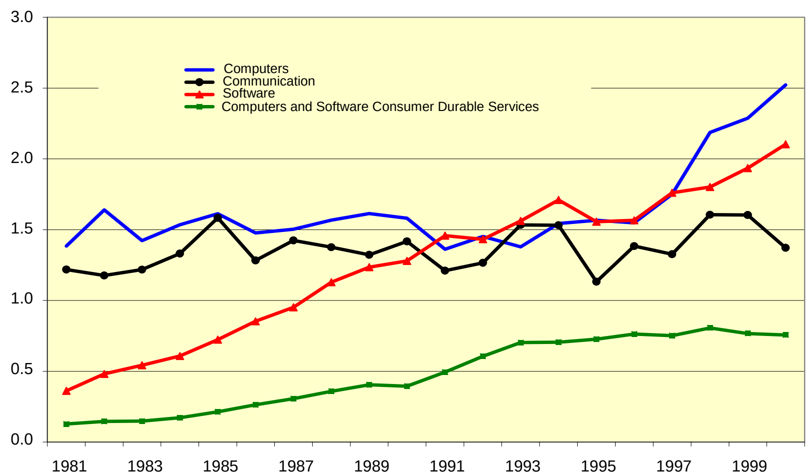
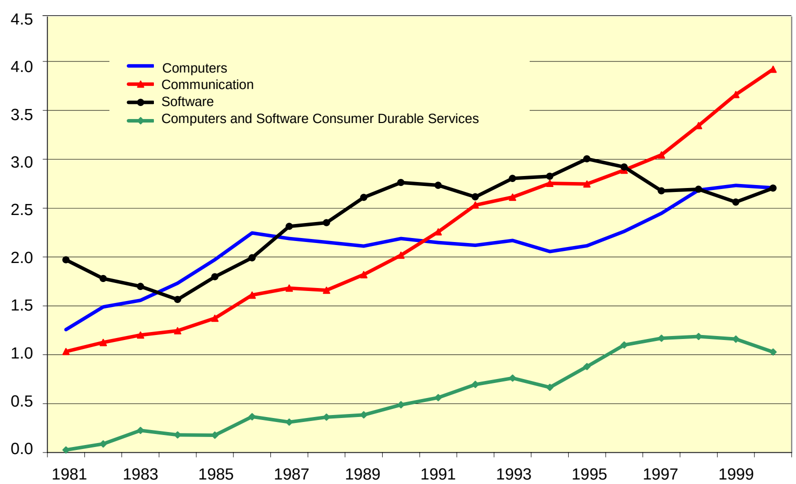


Figure 2b

Input Shares of Information Technology by Type, United States
(percent of current gross domestic capital income)



The rapid accumulation of software is less affected by services price declines in Canada than in the United States. In Canada, the price of software services fell 2.6 percent per year between 1995 and 2000, compared to 4.3 percent for the United States (see Tables 2a and 2b). Nonetheless, Canadian businesses have been accumulating software very rapidly, with real capital services growing 15.3 percent per year, significantly higher than the 8.5 percent increase per year in the United States. A possible explanation is that Canadians responded to computer price declines by investing more than their U.S. counterparts in complementary inputs like software. The services price decline of communication equipment fell 2.3 percent in the United States, compared to a 1.8 percent increase for Canada. As a result, the U.S. communication capital services grew faster than its Canadian counterpart during the period 1995-2000.

Tables 2a and 2b also present estimates of the flow of information technology capital services and corresponding price indexes for 1981-2000. Growth of information technology capital services jumped from 12.6 percent per year between 1988 and 1995 to 25.1 percent between 1995 and 2000 for the U.S., while growth of non-information technology capital services increased from 2.1 percent to 3.4 percent over the same period. This reverses the trend toward slower capital growth through 1995. In contrast, between these two periods, Canada's information technology capital services increased moderately from 15.6 percent to 22.0 percent, compared to an increase from 1.1 to 1.8 percent for non-information technology capital services over the same period.

Labour Services

This section presents estimates of university and non-university labour inputs for both the Canadian and U.S. private economies from 1981 to 2000. The primary data sources are the censuses of population (quinquennial for Canada and decennial for the United States), annual surveys (Labour Force Survey for Canada and Current Population Survey for the United States), the Canadian productivity accounts and the NIPAs for the United States for total hours worked and labour compensation.

The censuses of population provide detailed data on employment, hours, and labour compensation across demographic groups in census years. The annual survey data are used to interpolate similar data for intervening years and the Canadian productivity accounts and NIPA data provide control totals. The demographic groups include 112 different types of workers, cross-classified by class (employee, self-employed or unpaid), age (15-17, 18-24, 25-34, 35-44, 45-54, 55-64, 65+ years), gender, and education attainment (university and non-university).[11]

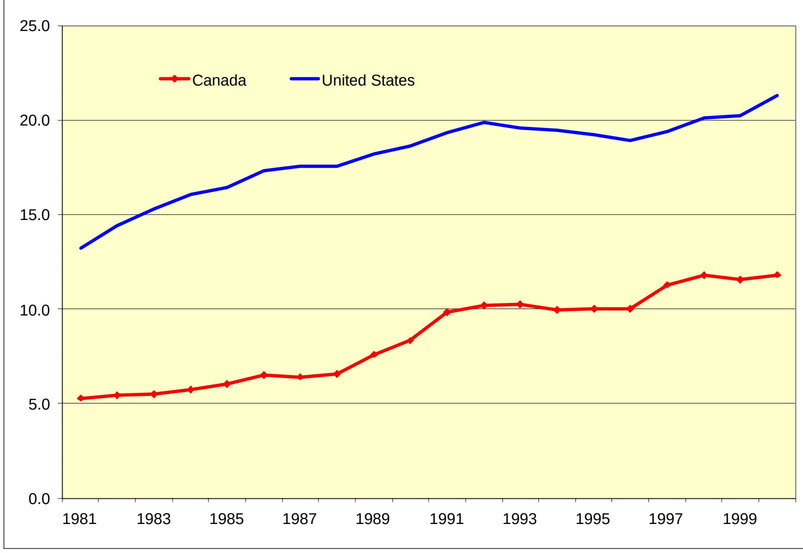
Constant quality indexes for the price and quantity of labour input account for the heterogeneity of the workforce across sex, employment class, age, and education levels. This follows the approach of Jorgenson, Gollop, and Fraumeni (1987) for the United States and Gu, Kaci, Maynard, and Sillamaa (2003) for Canada.

Table 2a and 2b present estimates of aggregate labour input by category of workers. The growth rate of labour input for Canada accelerated to 3.8 percent for the 1995-2000 period (2.5 percent for the United States) from 1.2 percent for the 1988-95 period (1.8 percent for the United States). This is primarily due to the growth of hours worked, which rose in Canada from a growth rate of 0.3 percent for the 1988-95 period (1.4 percent for the United States) to 3.1 percent for the 1995-2000 period (2.3 percent for the United States), as labour force participation increased and unemployment rates plummeted.

Figure 3 shows that the labour cost share of university-educated workers in the gross domestic income in current prices was 5.3 percent in 1981 in Canada (13.2 percent in the United States), but has risen fairly steadily since then until

Figure 3

Input Shares of University-educated Workers (percent of current gross domestic income)



the early 1990s when it experienced a significant slowdown. During the second half of the 1990s, this ratio experienced an unprecedented increase reaching 11.8 percent in 2000 (21.3 percent for the United States), more than double the performance posted in 1981. Tables 2a and 2b show that the growth of university-educated labour input significantly dominated that of non-university input across all periods. The substitution of university-educated workers for non-university workers has been an important force behind the restructuring of the Canadian and U.S. private economies. This reflects the increased role of knowledge workers associated by the deployment of information technology investment.

The Growth Resurgence Quantified

THE CANADIAN AND U.S. PRIVATE ECONOMIES have both undergone a remarkable resurgence since the mid-1990s with accelerating growth in output, multifactor productivity and labour productivity. This section quantifies the sources of growth for the 1981-2000 period and various sub-periods. An important objective is to account for the sharp acceleration in the level of economic activity since 1995 and, in particular, to document the role of information technology.

Contributions of Information Technology

Private business investment predominates in the output of information technology. Household purchases of information technology equipment and services are next in importance. Government purchases of information technology equipment and services, as well as net exports of information technology products, are also included in order to provide a complete picture. Firms, consumers, governments, and purchasers of Canadian exports have responded to relative price changes, increasing the contributions of computers, software, and communications equipment to GDP growth.

Tables 2a and 2b show that the price of computer investment in Canada fell by 16.7 percent per year, the price of software 1.0 percent, and the price of communications equipment 0.1 percent, and the price of information technology consumer durable services 10.5 percent during the period 1995-2000 (respectively 22.1 percent, 1.0 percent, 2.2 percent and 28.7 percent for the United States), while non-information technology prices rose 1.9 percent (1.7 percent for the United States). In response to these price changes, firms, households, and governments have accumulated computers, software, and communications equipment much more rapidly than other forms of capital.

Figures 4a, 4b, 5a and 5b highlight the rising contributions of information technology outputs to Canadian and U.S. economic growth. Figures 4a and 4b show the breakdown between information technology and non-information technology outputs, while Figures 5a and 5b decompose the contribution of information technology into its components.

Although the non-information segment remains the largest contributor to GDP growth, Figures 4a and 4b show that the output contribution of information technology during the post-1995 period more than doubled (0.8 percentage points compared to 0.3 percentage points in the 1980s; 1.4 percentage points up from 0.6 percentage points in the United States). Despite this increase, the bulk of GDP growth in the late 1990s in both Canada and the United States was ascribed to non-information technology (82 percent in Canada, compared to 71 percent in the United States). Figures 5a and 5b show that computer investment is the largest single information technology contributor in the late 1990s, but that investments in software and communications equipment have become increasingly important.

Figures 6a, 6b, 7a and 7b present a similar decomposition of information technology capital inputs. The contribution of these inputs to the growth of overall capital input has increased, albeit not to the same extent as that of information technology to output growth. Figures 6a and 6b show that information technology contribution to capital input has less than doubled in Canada between the 1980s and the late 1990s (from 0.8 percentage point to 1.3 percentage points). This contrasts markedly with the United States, where information technology contribution to capital input doubled during these two periods (2.4 percentage points, compared to 1.2 percentage points). Figures 7a and 7b show that, as in the case of the output, computers were the largest information technology contributor on the capital input side, reflecting the growing share and accelerating growth rate of computer investment in the late 1990s.

Figure 4a

Gross Domestic Product Contribution of Information Technology in the Canadian Private Economy (average annual percentage rates of growth)

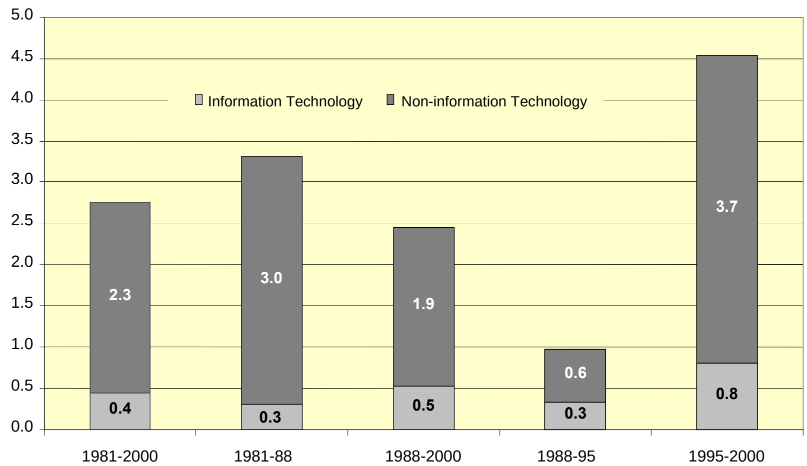


Figure 4b

Gross Domestic Product Contribution of Information Technology in the U.S. Private Economy (average annual percentage rates of growth)

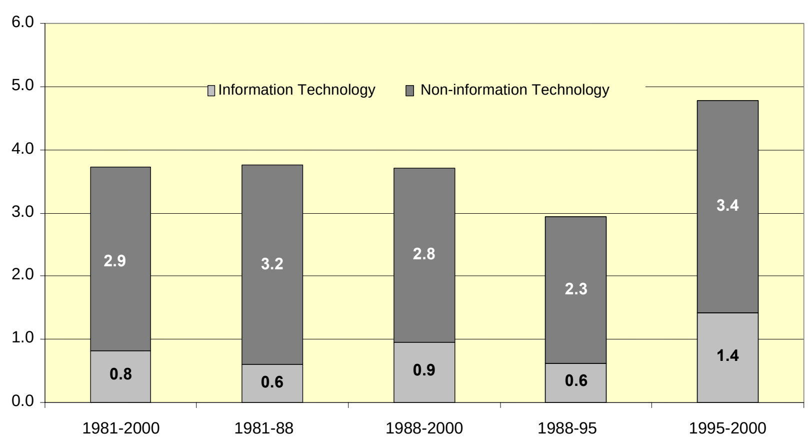


Figure 5a

Gross Domestic Product Contribution of Information Technology by Type in the Canadian Private Economy (average annual percentage rates of growth)

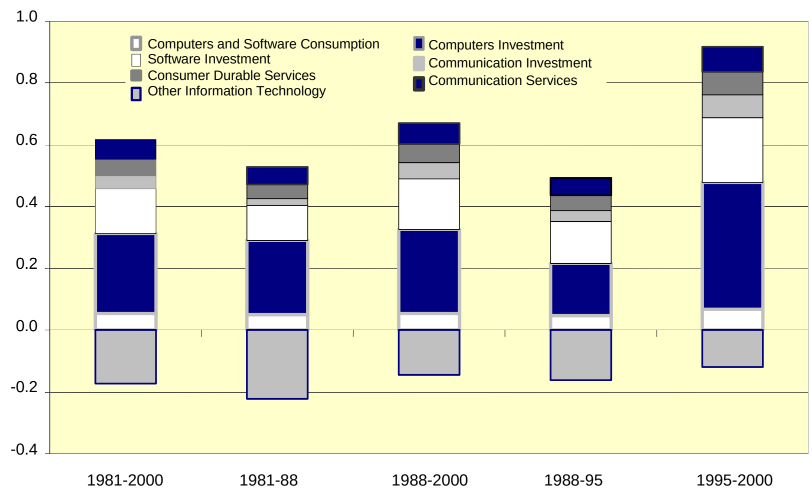


Figure 5b

Gross Domestic Product Contribution of Information Technology by Type in the U.S. Private Economy (average annual percentage rates of growth)

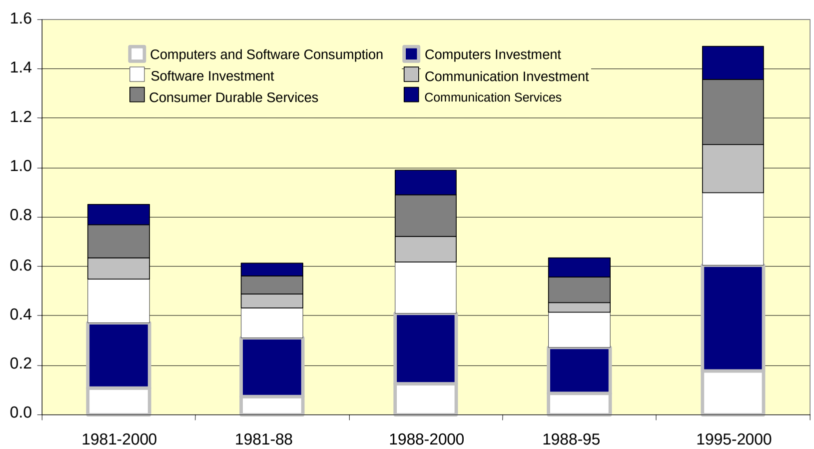


Figure 6a

Capital Input Contribution of Information Technology in the Canadian Private Economy (average annual percentage rates of growth)

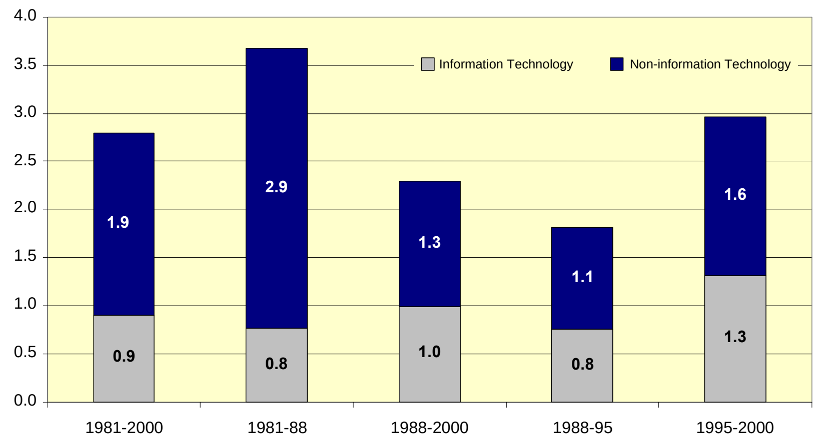


Figure 6b

Capital Input Contribution of Information Technology in the U.S. Private Economy (average annual percentage rates of growth)

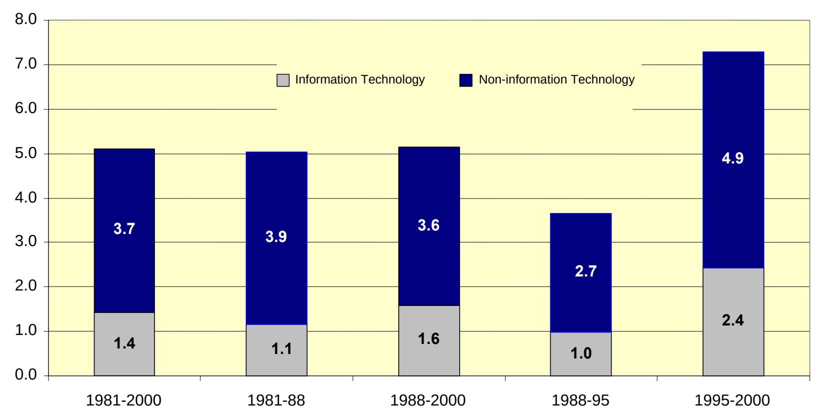


Figure 7a

Capital Input Contribution of Information Technology by Type in the Canadian Private Economy (average annual percentage rates of growth)

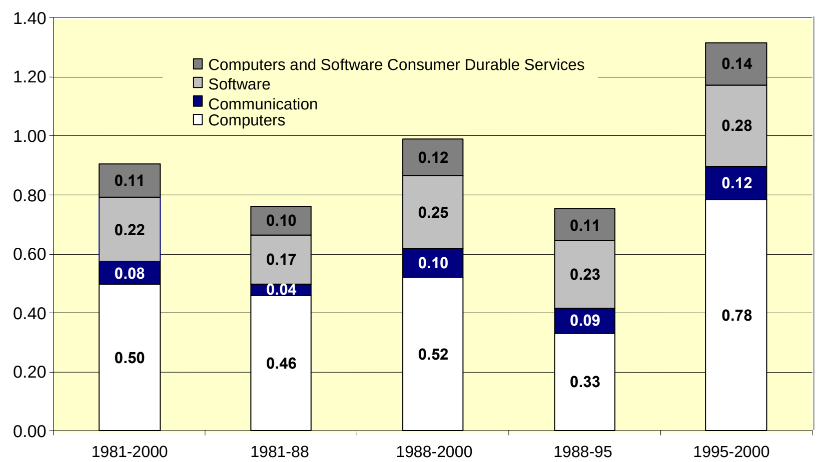
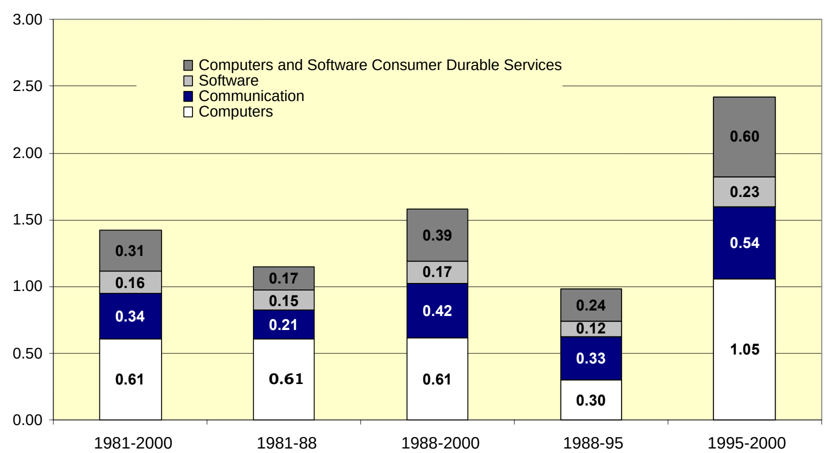


Figure 7b

Capital Input Contribution of Information Technology by Type in the U.S. Private Economy (average annual percentage rates of growth)



As indicated above, the structure of aggregate output has shifted toward information technology and the capital deployed in the economy has moved rapidly to information technology assets. Following these changes, the composition of the workforce has evolved toward more university-educated workers. As the unemployment rate fell in the late 1990s, workers with a wide variety of levels of education and experience entered the ranks of the employed labour force. The contribution of university-educated workers dominated the growth of labour input in the United States during the period 1981-2000, even though these workers are less numerous than non-university workers (Figures 8a and 8b and Table 1). This contrasts markedly with Canada where the growth of labour input was driven by non-university-educated workers. The contribution of university-educated workers to the aggregate labour input increased between the 1980s and the late 1990s in Canada but it declined in the United States, thereby reducing the gap between the two countries in this area.

In both countries, university-educated workers have higher marginal products on average, as can be seen in the college wage premium. In Canada, the wage premium for university-educated workers was $13,067 in 1981, $18,395 in 1988, $26,738 in 1995, and $31,806 in 2000 (in the United States, US$13,399 in 1981, US$20,453 in 1988, US$27,086 in 1995, and US$33,426 in 2000). The number of university-educated workers has been growing more rapidly than that of non-university workers. The modest contribution of university-educated workers in the labour input growth in Canada is partly explained by their small share in the gross domestic income, compared to their U.S. counterpart.

A possible explanation of the important contribution of university-educated workers (despite their small share) is that they are complementary to information technology capital, so that the decline in the price of information technology drives up the demand for both information technology capital and university-educated workers.[12] An alternative explanation is that productivity growth is biased toward university-educated workers, making them relatively more productive than non-university workers.

Figure 8a

Labour Input Contribution of University-educated Workers in the Canadian Private Economy (average annual percentage rates of growth)

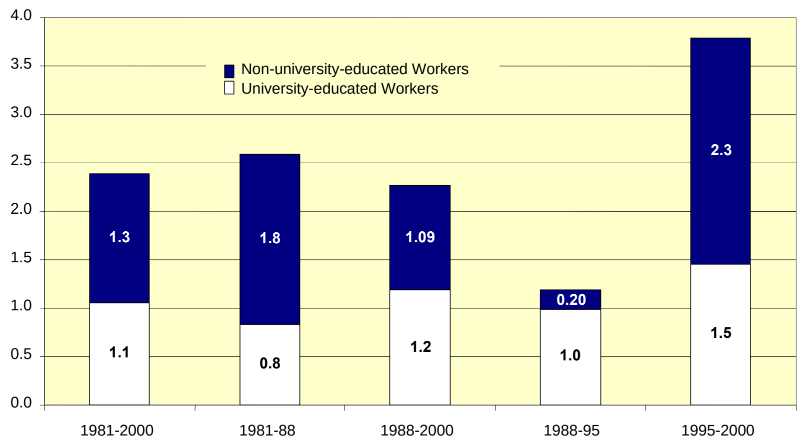
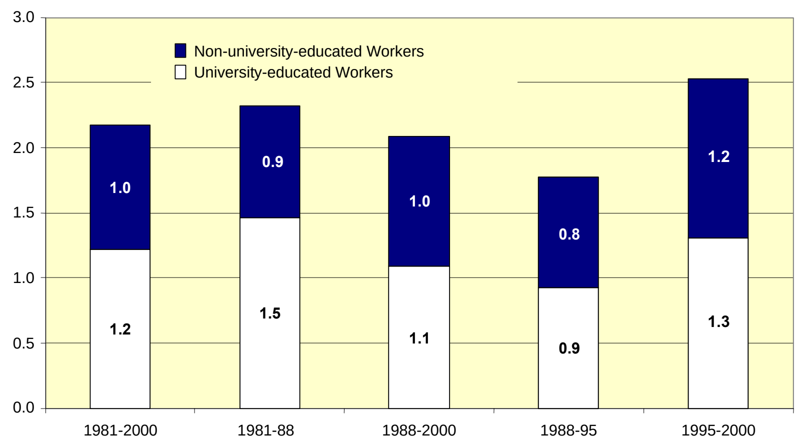


Figure 8b

Labour Input Contribution of University-educated Workers in the U.S. Private Economy (average annual percentage rates of growth)



Sources of Economic Growth

This section presents the sources of GDP growth for Canada and the United States over the entire period 1981 to 2000 and its various sub-periods. The contributions of capital inputs, labour inputs and multifactor productivity to GDP growth are reported in Tables 3a and 3b. In Canada, capital services contributed 1.35 percentage points, labour services 1.12 percentage points, and multifactor productivity growth 0.22 percentage points (for the United States, 1.81, 1.20 and 0.63 percentage points, respectively). Inputs growth was the source of 93 percent of Canadian economic growth over the past two decades, while multifactor productivity has accounted for 7 percent (17 percent for the United States).

A look at the Canadian economy before and after 1988 reveals some familiar features of the historical record. After a strong output growth and a modest multifactor productivity growth in the 1980s, the Canadian private economy slowed markedly through the 1990s, with output growth falling from 3.24 percent to 2.37 percent while multifactor productivity growth deteriorated from 0.51 percent to 0.06 percent. Growth in primary inputs also experienced a similar slowdown from 1.52 percent to 1.26 percent for capital input and from 1.23 percent to 1.06 percent for labour input. In contrast, the moderate U.S. slowdown in the growth of real GDP (from 3.76 percent to 3.70 percent) and primary inputs (from 3.19 percent to 3.04 percent) has resulted in improvements in multifactor productivity growth from 0.56 percent to 0.67 percent during the same period.

During the post-1995 period, labour input contributed 1.77 percentage points to the growth resurgence in Canada, compared with 1.68 percentage points for capital input. This contrasts with the United States where the contribution of capital input was larger than that of labour input (2.66 percentage points compared to 1.36 percentage points). Growth in hours worked accelerated as unemployment fell to a 10-year low. Labour markets have tightened considerably, even as labour force participation rates increased. University-educated workers contributed about two-thirds of a percentage point to Canada's GDP growth, while non-university workers added slightly more than percentage point (for the United States, 0.73 and 0.63 percentage points, respectively). Faster growth in multifactor productivity contributed the remaining 1.0 percentage points in Canada (0.76 percentage points for the United States).

Table 3a

Sources of Gross Domestic Product Growth, Canada (average annual growth percentage rates of growth)

	1981-2000	1981-88	1988-2000	1988-95	1995-2000
			Outputs		
Gross Domestic Product (GDP)	2.69	3.24	2.37	0.90	4.46
Contribution of Information Technology-GDP	0.43	0.30	0.51	0.31	0.79
Computer and Software Consumption	0.05	0.05	0.05	0.04	0.07
Computer Investment	0.25	0.24	0.26	0.16	0.40
Software Investment	0.14	0.11	0.16	0.12	0.20
Communication Investment	0.04	0.02	0.05	0.03	0.08
Consumer Durable Services	0.05	0.05	0.06	0.05	0.07
Communication Services	0.06	0.06	0.06	0.05	0.08
Other	–0.17	–0.22	–0.14	–0.15	–0.12
Contribution of Non-information Technology-GDP	2.26	2.95	1.86	0.59	3.68
Housing Services	0.38	0.40	0.37	0.38	0.35
Housing Investment	0.10	0.35	–0.05	–0.24	0.24
Other	1.79	2.21	1.54	0.46	3.09

Table 3a (cont'd)

Sources of Gross Domestic Product Growth, Canada (average annual growth percentage rates of growth)

	1981-2000	1981-88	1988-2000	1988-95	1995-2000
			Inputs		
Gross Domestic Income	2.47	2.74	2.31	1.51	3.45
Contribution of Capital Services	1.35	1.52	1.26	0.95	1.68
Contribution of Information Technology	0.44	0.31	0.54	0.39	0.75
Computers	0.24	0.19	0.28	0.17	0.44
Communication	0.04	0.02	0.05	0.04	0.07
Software	0.10	0.07	0.13	0.12	0.16
Consumer Durable Services	0.05	0.04	0.07	0.06	0.08
Contribution of Non-information Technology	0.91	1.20	0.72	0.56	0.94
Other Machinery and Equipment	0.16	0.11	0.21	0.09	0.37
Other Durables	0.10	0.25	–0.01	–0.10	0.13
Housing	0.39	0.58	0.25	0.36	0.07
Other	0.26	0.26	0.27	0.20	0.36
Contribution of Labour Services	1.12	1.23	1.06	0.56	1.77
University-educated Workers	0.50	0.40	0.56	0.47	0.68
Non-university-educated Workers	0.62	0.83	0.50	0.08	1.09
Multifactor Productivity	0.22	0.51	0.06	–0.60	1.01

Notes: The contribution of an output or an input is the rate of growth multiplied by the value share.
Contributions are defined in equation (2) in the text.

Table 3b

Sources of Gross Domestic Product Growth, United States (average annual growth percentage rates of growth)

	1981-2000	1981-88	1988-2000	1988-95	1995-2000
			Outputs		
Gross Domestic Product (GDP)	3.72	3.76	3.70	2.94	4.78
Contribution of Information Technology-GDP	0.82	0.60	0.95	0.61	1.42
Computers and Software Consumption	0.10	0.07	0.12	0.08	0.17
Computers Investment	0.26	0.23	0.27	0.18	0.41
Software Investment	0.17	0.12	0.20	0.14	0.28
Communication Investment	0.08	0.05	0.10	0.04	0.19
Consumer Durable Services	0.13	0.07	0.16	0.10	0.25
Communication Services	0.08	0.05	0.10	0.08	0.13
Other	0.00	0.00	0.00	0.00	0.00
Contribution of Non-information Technology-GDP	2.91	3.16	2.76	2.33	3.36
Housing Services	0.15	0.17	0.14	0.14	0.15
Housing Investment	0.17	0.30	0.09	0.01	0.20
Other	2.59	2.70	2.53	2.18	3.01

Table 3b (cont'd)

Sources of Gross Domestic Product Growth, United States (average annual growth percentage rates of growth)

	1981-2000	1981-88	1988-2000	1988-95	1995-2000
			Inputs		
Gross Domestic Income	3.09	3.19	3.04	2.34	4.02
Contribution of Capital Services	1.89	1.88	1.90	1.36	2.66
Contribution of Information Technology	0.53	0.43	0.58	0.37	0.88
Computers	0.23	0.23	0.23	0.11	0.38
Communication	0.13	0.08	0.15	0.12	0.20
Software	0.06	0.06	0.06	0.04	0.08
Consumer Durable Services	0.12	0.06	0.14	0.09	0.22
Contribution of Non-information Technology	1.37	1.46	1.32	0.99	1.78
Other Machinery and Equipment	0.56	0.49	0.60	0.39	0.89
Other Durables	0.36	0.45	0.31	0.24	0.42
Housing	0.24	0.25	0.23	0.21	0.27
Other	0.21	0.27	0.17	0.16	0.20
Contribution of Labour Services	1.20	1.31	1.14	0.98	1.36
University-educated Workers	0.77	0.76	0.78	0.89	0.73
Non-university-educated Workers	0.43	0.56	0.36	0.09	0.63
Multifactor Productivity	0.63	0.56	0.67	0.60	0.76

Notes: The contribution of an output or an input is the rate of growth multiplied by the value share. Contributions are defined in equation (2) in the text.

The contribution of capital input reflects the investment boom of the late 1990s as businesses, households, and governments poured resources into plant and equipment, especially computers, software, and communications equipment. The contribution of information technology capital services has grown steadily throughout the 1988-2000 period, a reflection of the impact of the accelerating decline in information technology prices. The contribution of information technology capital services was accompanied by a strong contribution of university-educated labour input.

After maintaining an average rate of 0.51 percent in Canada for the period 1981-88, multifactor productivity growth fell to -0.6 percent for the 1988-95 period and then vaulted to 1.01 percent per year for 1995-2000. This is a major source of growth in output and labour productivity for the Canadian private economy. While multifactor productivity growth for the 1995-2000 period is lower than the rate of the sixties, the Canadian private economy is recuperating from the anemic productivity growth of the past 15 years.

Results show that recent resurgence of the Canadian private economy has raised the growth rate of real GDP by 3.56 percentage points when 1995-2000 is compared to 1988-95 (1.84 percentage points in the United States). Capital input contributed 0.73 percentage points to the post-1995 revival (1.30 percentage points for the United States); about half of this contribution of capital input in Canada is due to the surge of information technology capital input, while the other half is due to a more rapid accumulation of non-information technology assets. This contrasts with the United States where almost two-thirds of the increase in capital input between these two periods was attributable to non-information technology (0.79 percentage points compared to 0.51 for information technology). Labour input contributed 1.21 percentage points to the growth resurgence (0.38 percentage points for the United States). University-educated workers contributed slightly more than two-tenths of a percentage point, while non-university workers added close to another percentage point to the growth resurgence. In the United States, university-educated workers have made a negative contribution to overall labour input growth (-0.16 percentage points), compared to a 0.54 percentage points increase for non-university-educated workers. Faster growth in multifactor productivity in Canada contributed the remaining 1.61 percentage points (0.16 percentage points for the United States). [13]

Sources of Labour Productivity Growth

Output growth is the sum of growth in hours worked and labour productivity. Table 4 shows the breakdown between growth in hours and labour productivity for the same periods as in the previous tables. For the period 1981-2000, labour productivity growth in Canada has not predominated in output growth, increasing just over 1.01 percent per year for this period, while hours increased about 1.64 percent per year. This contrasts with the United States where labour productivity was equally important as hours at work in the source of output growth, accounting for 49 percent of the output growth (38 percent for Canada).

Labour productivity growth depends on capital deepening, labour quality growth, and the growth of multifactor productivity. We have divided capital deepening between information technology and non-information technology capital inputs and labour quality among university-educated and non-university workers and the reallocation of hours between these two categories of workers.

Table 4 reveals the well-known productivity slowdown of the early 1990s, compared to the 1980s, but also emphasizes the acceleration in labour productivity growth in the late 1990s. The slowdown through the early 1990s reflects primarily reduced multifactor productivity growth in Canada (capital deepening in the United States). The growth of labour productivity slipped in Canada during the early 1990s with a slump in multifactor productivity (in Canada) and capital deepening (in the United States) only partly offset by a revival in labour quality growth. A slowdown in hours combined with slowing labour productivity growth during 1988-95 gave rise to a further slide in the growth of output.

Accelerating output growth between the periods 1988-95 and 1995-2000 in Canada reflects primarily growth in labour hours, vaulting from 0.28 percent to 3.11 percent (1.42 percent to 2.26 percent in the United States) and labour productivity, which increased from 0.62 percent to 1.31 percent during this period (from 1.51 percent to 2.46 percent in the United States). The sources of the productivity revival are different in Canada and the United States. In Canada, multifactor productivity contributed 1.01 percentage points (or 77 percent of labour productivity growth), offsetting the slump in both capital deepening and labour composition. In the United States, capital deepening and multifactor productivity contributed, respectively, 1.57 and 0.76 percentage points, (accounting, respectively, for 31 percent and 64 percent to labour productivity growth), largely offsetting the labour quality slowdown. Reallocation of hours, a reflection of the shift of the workforce toward more productive activities, has made an important contribution.

Table 4

Sources of Labour Productivity Growth (average annual percentage rates of growth)

	1981-2000		1981-88		1988-2000		1988-95		1995-2000	
	Canada	United States	Canada	United States	Canada	United States	Canada	United States	Canada	United States
Labour Productivity	1.03	1.83	1.25	1.70	0.91	1.90	0.62	1.51	1.31	2.46
Gross Domestic Product	2.69	3.72	3.24	3.76	2.37	3.70	0.90	2.94	4.46	4.78
Hours Worked	1.64	1.86	1.97	2.02	1.45	1.77	0.28	1.42	3.11	2.26
Contribution of Capital Deepening	0.47	1.04	0.46	0.98	0.47	1.08	0.79	0.72	0.03	1.57
Information Technology	0.34	0.42	0.19	0.34	0.52	0.46	0.39	0.29	–0.27	0.69
Non-information Technology	0.13	0.62	0.27	0.64	–0.05	0.62	0.40	0.43	0.29	0.88
Contribution of Labour Composition	0.34	0.16	0.28	0.16	0.38	0.16	0.44	0.19	0.28	0.13
University-educated Workers	0.03	–0.02	0.02	–0.05	0.04	–0.01	0.05	0.00	0.02	–0.01
Non-university-educated Workers	0.19	0.06	0.19	0.04	0.19	0.07	0.22	0.10	0.14	0.04
Reallocation of Hours	0.12	0.12	0.07	0.18	0.15	0.09	0.17	0.09	0.12	0.10
Multifactor Productivity	0.22	0.63	0.51	0.56	0.06	0.67	–0.60	0.60	1.01	0.76
Information Technology	0.07	0.33	0.06	0.28	0.07	0.35	0.04	0.22	0.11	0.54
Non-information Technology	0.13	0.30	0.35	0.28	0.00	0.32	–0.69	0.38	0.98	0.22

The Sectoral Sources of Multifactor Productivity Growth

Motivation

We have explored the sources of the Canadian and the U.S. economic growth at the aggregate level and demonstrated that accelerated multifactor productivity growth is an important contributor to the recent growth resurgence—particularly in Canada. We now turn our attention to industry data to trace the contribution of information technology-producing industries to aggregate multifactor productivity growth. Before proceeding to the sectoral allocation of multifactor productivity gains, it is useful to note that Ho, Rao, and Tang, in this volume, also examines sectoral allocations. It is important, however, to note that there are differences in the coverage of information technology-producing industries, the domain of definition of the aggregate multifactor productivity growth and the aggregation methodology.

First, Ho, Rao and Tang use the notion of business sector employed by the Canadian productivity accounts and the BLS, a narrower coverage than the notion of private economy employed in our study. In addition to the business sector, the latter includes owner-occupied dwellings and the service flows of consumer durables. Second, our method uses a top-down approach, compared to a bottom-up approach in Ho, Rao and Tang. Third, information technology-producing industries are defined to include two manufacturing industries that produce information technology assets (computers, telecommunication equipment and software) and semi-conductors: computers, and communications and electronic equipment. In contrast, Ho, Rao and Tang add communication services to these two manufacturing industries. Despite these differences, the same broad trends emerge and therefore attest to the robustness of the findings.

Methodology and Data Sources

This section summarizes the methods for allocating the sources of aggregate economic growth to the sectoral level. The first component consists of a production function for each industry with gross output expressed as a function of capital, labour, intermediate inputs and the level of technology. The second is the Domar methodology for aggregating over industries to obtain an aggregate measure of productivity. The remainder of this section summarizes our methodology and the underlying data sources and discusses the results.

The conceptual distinction between industry and aggregate productivity indexes has long been recognized. Domar (1961) developed an internally consistent link by expressing the rate of aggregate multifactor productivity growth as a weighted average of industry productivity growth rates, with weights equal to the ratios of industry gross output to aggregate GDP. Domar weights have the notable feature that they do not sum to unity. This reflects the different output concepts used at the aggregate and industry levels. At the aggregate level, only primary inputs are included, while both primary and intermediate inputs are included in the industry production functions. For the same industry, gross output exceeds value added, so the sum of gross output across industries exceeds the sum of value added. This weighting methodology implies that the private economy-wide multifactor productivity growth can grow faster than productivity in any industry, since productivity gains are magnified as they work their way through the production process.

This internally consistent framework makes it possible to identify the role of information technology production as a source of productivity growth at the sectoral level. Jorgenson, Gollop, and Fraumeni (1987) have employed Domar's (1961) model to trace aggregate productivity growth to its sources at the level of individual industries. More recently, Jorgenson and Stiroh (2000), and Jorgenson, Ho, and Stiroh (forthcoming), for the United States, and Harchaoui and Tarkhani (2004a), for a Canada-U.S. comparison, have used the same framework to quantify the contribution of information technology-producing industries to the business sector multifactor productivity revival.

Before turning to the results, a description of the data sources is in order. The primary source of information at the industry level is the KLEMS database for both countries maintained, respectively, by the Canadian Productivity Accounts and Dale Jorgenson and his associates. Both data sources employ similar concepts and methods that accord with the OECD productivity manual (OECD 2001). These data include series in chained constant dollars for output, capital, labour and intermediate inputs, along with the current dollar cost of each of these inputs. At the industry level, computers and communications and electronic equipment constitute the two manufacturing industries that make up the information technology-producing industries for Canada and the United States. Although these two industries account for a small share in the aggregate GDP in both Canada and the United States, they have experienced a rapid output growth over the last 20 years.

Before proceeding to the empirical results, we should point out two features of the data employed in industry-level analysis. First, the Canadian Productivity

Account (CPA) series on gross output and intermediate inputs are usually three years behind the reference year due to the long lag in obtaining detailed inter-industry transactions from Statistics Canada input-output tables. To capture most of the growth revival experienced by the Canadian business sector in the late 1990s, these series were updated on an experimental basis using synthetic input-output tables for the post benchmark years. Despite the preliminary nature of the projected series for the 1998-2000 period, their overall trend over the 1981-2000 period appears to be reasonable and consistent with other current series such as investment or value added by industry.

Second, our estimates of capital services at the industry level are not directly comparable to the aggregate series employed in the previous sections of this study. In the first part of the study, we have used a production possibility frontier which requires an aggregate measure of capital services $\left(K_t = f\left(K_{1,t}, K_{2,t}, ..., K_{n,t}\right)\right)$, where n includes all types of reproducible fixed assets, inventories and land. In this section, we assume the existence of a production function at the industry level, which implies that capital services are aggregated across assets and industries.

Empirical Results

Figures 9a and 9b report the contribution of information technology and non-information technology industries to the aggregate multifactor productivity growth in Canada and the United States. Canada's information technology-producing industries have consistently made a positive, albeit small, contribution to the aggregate productivity growth. Compared to the early 1980s, their contribution during the second half of the 1990s almost doubled to reach 0.12 percentage points. In contrast, information technology-using industries have generated the bulk of the aggregate multifactor productivity in Canada during the early 1980s and late 1990s; but their contribution has been negative in the early 1990s, thereby explaining, to a large extent, the fortunes of the aggregate productivity performance in Canada during that period. While close to 80 percent of the multifactor productivity performance in Canada during the late 1990s was driven by information technology-using industries, the story is different for the United States, where these industries have generally generated about 25 percent of the aggregate productivity gains. This result is consistent with the one reported in Harchaoui and Tarkhani (2004a), based on a different methodology from the one employed in this study.

Figure 9a

Sectoral Contributions of Information Technology to Canada's Multifactor Productivity Growth, Private Economy (Average annual percentage rates of growth)

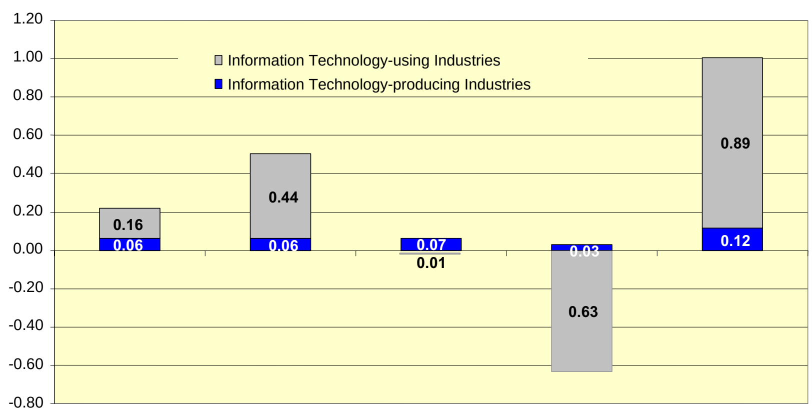
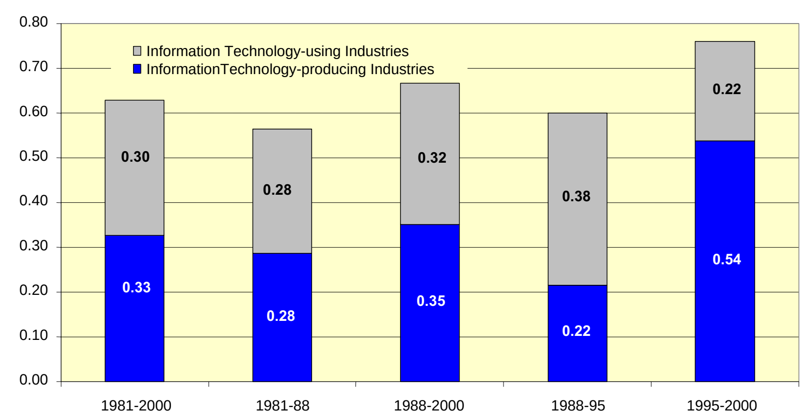


Figure 9b

Sectoral Contributions of Information Technology to U.S. Multifactor Productivity Growth, Private Economy (average annual percentage rates of growth)



The difference in the sectoral sources of multifactor productivity between Canada and the United States may be the result of differences in the structure of the economies and/or in the sources, concepts and methods that underlie the statistical systems of the two countries. Differences in the measurement of information technology prices has long been considered as the prime suspect of the Canada-U.S. manufacturing sector's productivity gap in the Canadian public policy debate. As shown by Table 5, the price changes have significant impacts on the productivity performance of information technology-producing industries. It is therefore important to ascertain the extent to which these price differences account for the sectoral allocation of the multifactor productivity growth.

During the 1981-2000 period, the annual growth rate of computers and office equipment industry's output implicit prices declined by 12.7 percent in Canada, slightly slower than the 14.5 percent drop for their U.S. counterparts. This contrasts with the communication and electronic products industry which showed diverging trends between the two countries: a 0.9 percent increase for Canada, compared

Table 5

Output and Intermediate Inputs Implicit Prices of Information Technology-producing Industries (average annual growth rate in percent)

		1981-2000	1995-2000
Canada			
Output	Computers and Office Equipment	–12.7	–18.6
	Communication and Electronic Products	0.9	–1.6
	Information Technology-producing Industries	–3.0	–6.0
Intermediate Inputs	Computers and Office Equipment	–9.4	–17.1
	Communication and Electronic Products	2.1	0.7
	Information Technology-producing Industries	–1.0	–3.5
United States			
Output	Computers and Office Equipment	–14.5	–22.1
	Communication and Electronic Products	–6.1	–12.8
	Information Technology-producing Industries	–9.5	–16.2
Intermediate Inputs	Computers and Office Equipment	–6.1	–11.9
	Communication and Electronic Products	–2.1	–7.0
	Information Technology-producing Industries	–3.1	–7.7

to a 6.1 percent decline for the United States. The implicit prices for the intermediate inputs showed similar diverging trends for the communication and electronic products industry (a 2.1 percent increase for Canada, compared to a 2.1 percent decline for the United States), whereas those of the computers and office equipment industry declined faster in Canada compared to the United States (9.4 percent and 6.1 percent, respectively). This discrepancy becomes wider in the late 1990s, due to the relentless decline in the prices of information technology output in the United States.

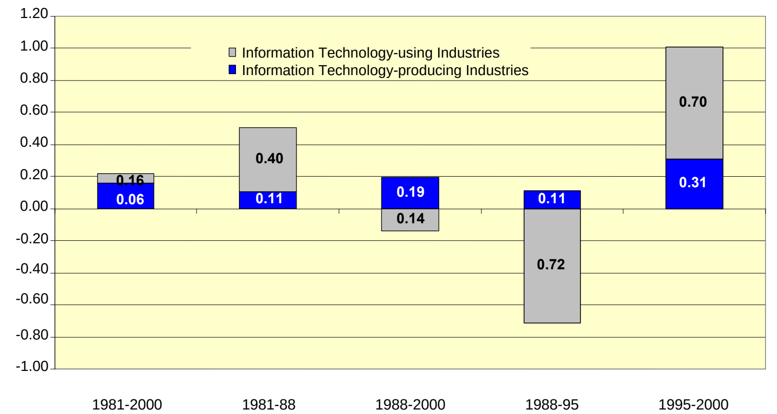
In order to make a rigorous comparison between the role of information technology-producing industries in productivity performance in Canada and the United States, we have introduced an *internationally harmonized* deflator for information technology-producing industries' output and intermediate inputs, based on the implicit prices (adjusted for the exchange rate) from the U.S. KLEMS database. The harmonized deflator drops much faster than the prices in the Canadian productivity accounts. We investigate how this affects our estimates.

With the harmonized price indexes, although multifactor productivity growth of Canadian information technology-producing industries improved from 3.1 percent to 7.2 percent, it still shows a 1.7 percentage point gap in favour of their U.S. counterparts. This gap reflects the joint effect of the exchange rate and the differences in the structures of the information technology-producing industries between Canada and the United States. Although it is difficult to quantify the impact of each of these effects, the importance of the difference in the structures cannot be negligible.

In both countries, multifactor productivity of computers and office equipment grew at more than twice the rate of communication and electronic equipment. However, the relative size of the two industries in the two countries showed significant differences. In the late 1990s, the communication and electronic equipment industry accounted for three-quarters of Canadian information technology-producing industries, up from 68.1 percent in 1981. This contrasts markedly with the United States, where this industry is much smaller, accounting for slightly more than one third of the information technology-producing industries output in the late 1990s, down from 43.2 percent in 1981. Therefore, the least performing information technology-producing industry has seen its relative share increasing in Canada and vice versa in the United States. This suggests that the role of economic structure in the Canada-U.S. multifactor productivity gap of information technology-producing industries cannot be ruled out.

Figure 10

Sectoral Contributions of Information Technology to Canada Multifactor Productivity Growth Using International Harmonized Prices, Private Economy (average annual percentage rates of growth)



Despite this difference in the structure of the information technology-producing industries, it is informative to examine how these harmonized price indexes affect our results on the sectoral allocation of aggregate multifactor productivity growth. Figure 10 shows that with the use of harmonized prices, the contribution of information technology-producing industries to the Canadian productivity revival almost tripled, averaging 0.31 percentage points during the post-1995 period. Despite this increase, the basic story remains unchanged—the bulk of the Canadian multifactor productivity revival was attributable to information technology-using industries.

Concluding Remarks

THIS STUDY HAS EMPLOYED NEW DATA on the sources of growth for the Canadian and U.S. private economies over the period 1981-2000. There are several innovations implemented in this study.

First, our definition of the private economy is broader than the notion of business sector employed in our previous work. In particular, we treat consumer durable goods symmetrically with housing capital since both are essentially investment goods that provide a flow of services over many periods.

Second, we made the distinction between university-educated workers and non-university-educated workers to compare the role of knowledge workers and information technology assets in the growth resurgence in Canada and the United States.

Third, an important feature of the accounting framework is the explicit role of intermediate inputs at the industry level. Price declines resulting from imported information technology in Canada and improvements in semiconductor technology in the United States are, to a large extent, reflected in the large contributions of intermediate inputs of information technology-producing industries of these two countries.

The results indicate that the mechanisms underlying the structural transformation of the Canadian and the U.S. private economies are readily apparent in the data. The structure of aggregate GDP has been shifting toward information technology commodities. The capital deployed in the economy is moving rapidly toward information technology assets. Finally, the composition of the work force is evolving toward more university-educated workers as investments in higher education continue to rise.

As an illustration, consider the increasing role that information technology played as a source of economic growth. For the period 1981 to 1988, information technology-GDP contributed less than one-tenth of one percent to Canada's economic growth (16 percent for the United States). Since 1995, however, the price of information technology has fallen at historically unprecedented rates, and firms and households have followed a basic principle of economics — they have substituted towards relatively cheaper commodities. Since 1995, the price decline for information technology has accelerated, reaching 4.3 percent per year from 1995 to 2000 (9 percent for the United States). In response, investment and consumption in information technology have exploded and the growth contribution of information technology-GDP almost doubled to 0.18 percentage points per year in the late 1990s (0.30 percentage points for the United States). The larger share of information technology in the United States, compared to Canada, accounts for much of the difference in these contributions.

Next, consider the acceleration of labour productivity growth in the 1990s. After a seven-year slowdown dating back to the early 1990s, Canada's labour productivity grew 1.31 percent per year for the 1995-2000 period (2.46 for the United States), a 0.69 percentage point faster than during the 1990-95 period (close to 1 percentage point for the United States). A detailed decomposition shows that information technology capital deepening retarded labour productivity growth in Canada (–0.27 percentage points) as a result of the remarkable increase in hours at work, but added 0.69 percentage points to the U.S. labour productivity growth. Non-information technology capital deepening has made a 0.29 percentage points contribution to labour productivity in Canada, compared to 0.88 percentage point for the United States.

Slowing labour quality growth retarded Canada's labour productivity growth by 0.16 percentage points (0.06 percentage points for the United States), relative to the early 1990s, a result of exhaustion of the pool of available workers. The contribution of non-university-educated workers dominated that of university-educated workers in both Canada and the United States. Reallocation of hours, a reflection of the shift of the workforce toward more productive activities, has also made an important contribution.

Faster multifactor productivity growth contributed an additional 1 percentage point in Canada (0.76 percentage points in the United States), largely reflecting different sectoral sources of technical change resulting from the acceleration in the information technology price decline. A closer look at the data showed that gains in U.S. multifactor productivity growth can be traced, in substantial part, to information technology-producing industries, which produce computers, semiconductors, and other high-tech gear. The evidence is equally clear that information technology-using industries like finance, insurance, and real estate, and distributive trade industries have been the source of Canada's multifactor productivity revival.

Endnotes

1 See Jorgenson and Stiroh (2000), Jorgenson (2001), Jorgenson, Ho, and Stiroh (forthcoming), as well as Baily (2002), Congressional Budget Office (2002), Council of Economic Advisors (2002), Gordon (2002), McKinsey Global Institute (2001), Oliner and Sichel (2000, 2002), and Whelan (2002).

2 See Harchaoui, Tarkhani, Jackson and Armstrong (2002) and Harchaoui and Tarkhani (2004a).

3 See Baldwin and Harchaoui (2003).

4 Our previous studies employed official U.S. data from the U.S. Bureau of Labor Statistics (BLS). In the present study, we use Dale Jorgenson's KLEMS database, a data source that is not directly comparable to its official U.S. counterpart from the BLS. The former uses the notion of gross output (sectoral output for the BLS) and labour input (hours at work for the BLS) at the industry level. Owner-occupied dwellings and the service flows of durables are in scope in Jorgenson's data but out of BLS scope.

5 In the system of national accounts, capital formation is confined to institutional units in their capacity as producers. Thus, there is no gross fixed capital formation of households, unless they are producers. One consequence is that persons who own the dwellings in which they live are treated as unincorporated enterprises that produce housing services that are consumed by the household to which the owner belongs. This activity is excluded from the coverage of the Canadian productivity accounts and the U.S. official productivity program, maintained by the U.S. BLS. Similarly, the imputed income generated by the fictitious unincorporated enterprises is also excluded from the production side of the productivity accounts.

6 Under the existing practice, personal expenditure is not a true measure of consumption. Under the existing conventions, purchases of consumer durables are expensed in the period when transactions occur. Since durable goods have a service life of more than one year, this treatment fails to capture the service flow from the stock of durables throughout their length of life, thereby making the conventions for the measurement of consumer durables not symmetrical with those of housing. This is by no means the first time that Statistics Canada has explored the construction of estimates for the flow of services for consumer durables. See Johal (1992).

7 See Katz and Peskin (1980) and the references therein. Katz and Peskin derived experimental estimates of consumer durables flow of services for the United States. A similar work for Canada was performed by Johal (1992).

8 Note that our output and capital services flow concepts include the service flows from residential structures and consumer durables.

9 See Harchaoui and Tarkhani (2004b) for a description of the methodology.

10 At the time this study was written, Statistics Canada has not introduced capitalized software expenditures in the data prior to 1981.

11 In Canada and the United States, university labour input comprises all employees with a B.A. and above.

12 Gu and Wang in this volume found that Canadian industries that are both information technology intensive and skill intensive had larger productivity gains in the post-1995 period. This finding tends to support the complementarity explanation between skilled workers and information technology capital.

13 These results are generally consistent with those of Ho, Rao and Tang in this volume who also found that Canada has experienced a more rapid surge in economic growth and labour input growth than the United States.

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Bibliography

Baily, M.N. "The New Economy: Post Mortem or Second Wind." *Journal of Economic Perspectives* 16 (2002): 3-22.

Baldwin, J.R., and T.M. Harchaoui, eds. *Productivity Growth in Canada – 2002*. Ottawa: Statistics Canada Catalogue No. 15-204 XPB, 2003.

Bureau of Labor Statistics. "Multifactor Productivity Trends." USDL 02-36. February 11, 2002.

Christensen, L.R., and D.W. Jorgenson. "Measuring Economic Performance in the Private Sector." In *The Measurement of Economic and Social Performance*. Edited by Milton Moss. New York: National Bureau of Economic Research, 1973.

Congressional Budget Office. *The Budget and Economic Outlook: Fiscal Years 2003-2012*. 2002.

Council of Economic Advisors. *Economic Report of the President*. Washington: U.S. Government Printing Office, February 2002.

Domar, E. "On the Measurement of Technological Change." *Economic Journal* 71 (1961): 709-729.

Dougherty, C., and D.W. Jorgenson. "There is No Silver Bullet: Investment and Growth in the G7." *National Institute Economic Review* 162 (October 1997): 57-74.

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

Gordon, R.J. *Technology and Economic Performance in the U.S. Economy*. NBER Working Paper No. 8771. February 2002.

Gu, W., and W. Wang. *Information Technology and Productivity Growth: Evidence from Canadian Industries*. Chapter 3 in this volume, 2004.

Gu, W., M. Kaci, J.-P. Maynard, and M. Sillamaa. "The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin, and T.M. Harchaoui. Ottawa: Statistics Canada Catalogue No. 15-204-XPE, 2003.

Harchaoui T.M., and F. Tarkhani. "A Comprehensive Revision of the Capital Input Methodology for Statistics Canada Multifactor Productivity." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin, and T.M. Harchaouié. Ottawa: Statistics Canada Catalogue No. 15-204-XPE, 2003.

——. *Whatever Happened to Canada-U.S. Economic Growth and Productivity Performance in the Information Age*? Economic Analysis Research Paper Series. Ottawa: Statistics Canada (Analytical Studies Branch), 2004a. Forthcoming.

——. *Accounting for Housing and Services Flow of Consumers' Durables in the Canadian Productivity Accounts*. Methodology Series. Ottawa: Statistics Canada (Analytical Studies Branch), 2004b. Forthcoming.

Harchaoui, T.M., F. Tarkhani, C. Jackson, and P. Armstrong. "A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies." *Monthly Labor Review* 125, 3 (October 2002): 31-47.

Ho, M.S., and D.W. Jorgenson. "The Quality of the U.S. Workforce, 1948-95." Harvard University, 1999. Manuscript.

Ho, M.S., S. Rao, and J. Tang. *Sources of Output Growth in Canadian and U.S. Industries in the Information Age*. Chapter 4 in this volume, 2004.

Johal, K. "A Study of the Flow of Consumption Services from the Stock of Consumer Goods." Technical Series No. 18. Ottawa: Statistics Canada (National Accounts and Environment Division), 1992.

Jorgenson, D.W. “Information Technology and the U.S. Economy.” *American Economic Review* 91 (2001): 1-32.

Jorgenson, D.W., and Z. Griliches, “The Explanation of Productivity Change.” *Review of Economic Studies* (July 1967): 249-283.

Jorgenson, D.W., and K.J. Stiroh. “Raising the Speed Limit: U.S. Economic Growth in the Information Age.” *Brookings Papers on Economic Activity* 1 (2000): 125-211.

Jorgenson, D. W., and E. Yip. “Whatever Happened to Productivity Growth in the G-7?” In *New Developments in Productivity Analysis*. Edited by C.R. Hulten, E.R. Deau and M.J. Harper. Chicago: University of Chicago Press, 2001.

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

Jorgenson, D.W., M.S. Ho, and K.J. Stiroh. “Growth of U.S. Industries and Investments in Information Technology and Higher Education.” In *Measurement of Capital in the New Economy*. Edited by C. Corrado, J. Haltiwanger and D. Sichel. Chicago: University of Chicago Press. Forthcoming.

Katz, A.J., and J. Peskin. “The Value of Services Provided by the Stock of Consumer Durables, 1947-77: An Opportunity Cost Measure.” *Survey of Current Business* 60 (1980): 22-31.

McKinsey Global Institute. *U.S. Productivity Growth, 1995-2000: Understanding the Contribution of Information Technology Relative to Other Factors*. Washington: McKinsey Global Institute, October 2001.

OECD. *OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth*. Paris: Organisation for Economic Co-operation and Development, 2001.

Oliner, S.D., and D.E. Sichel. “The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?” *Journal of Economic Perspectives* 14 (2000): 3-22.

——. “Information Technology and Productivity: Where are We Now and Where are We Going?” Federal Reserve Bank of Atlanta, *Economic Review,* 2002.

Statistics Canada. *The Daily*. July 2002.

Whelan, K. “Computers, Obsolescence, and Productivity.” *Review of Economics and Statistics* 84 (2002): 445-462.

Information Technology and Productivity Growth: Evidence from Canadian Industries

3

Wulong Gu & Weimin Wang

Abstract

LABOUR PRODUCTIVITY GROWTH ACCELERATED in the Canadian business sector after 1995. Our analysis shows that the rise in multi-factor productivity (MFP) growth was the main contributing factor. Information technologies (IT) made little direct contribution to the labour productivity growth revival through capital deepening. However, our results show that IT use is linked to the MFP growth acceleration through IT-induced organizational innovation and network or spillover effects. Our results also show that the industries with larger shares of knowledge workers are more likely to benefit from IT. There is some evidence to suggest that manufacturing industries that are more open to international trade have larger productivity gains from IT.

Introduction

PRODUCTIVITY GROWTH ACCELERATED in the Canadian business sector in the second half of the 1990s. This pick-up occurred somewhat later in Canada than in the United States (Robidoux and Wong, 2003; Faruqui, Gu, Kaci, Laroche, and Maynard, 2003; Armstrong, Harchaoui, Jackson, and Tarkhani, 2002; Crawford, 2002). Between the 1988-95 and 1995-2000 periods, annual labour productivity growth in the Canadian business sector rose from 1.56 percent to 1.91 percent. Annual multifactor productivity growth increased from 0.57 percent to 1.06 percent. The objective of this study is to examine the sources of the productivity growth revival in the Canadian business sector. In particular, we will examine the issue of whether this productivity growth revival is linked to the use of information technologies (IT).

A large number of studies in the United States conclude that the productivity growth revival in the United States is due to IT production and IT use (Jorgenson, Ho, and Stiroh, 2002; Pilat and Lee, 2001). A number of studies in Canada find that the pickup in productivity growth in Canada is due to the increase in productivity growth in the service sectors such as wholesale and retail trade, and communication services (Faruqui, et al, 2003; Rao and Tang, 2001). As the services sector has invested heavily in IT during the 1990s, these studies infer that the productivity growth pickup is linked to IT in Canada as is the case for the United States (Colecchia and Schreyer, 2002) .

Most existing studies have focused on the contribution of IT use and IT production to productivity growth in Canada and the United States. The use of IT contributes to labour productivity growth through capital deepening as industries increased their investments in IT.[1] The production of IT contributes to labour productivity growth through rapid technological progress and strong multifactor productivity growth in IT-producing industries.

A number of recent papers in the United States have begun to examine a related question: Is IT use linked to strong multifactor productivity growth during the second half of the 1990s (Stiroh, 2002a; Basu, Fernald, Oulton, and Srinivasan, 2003)? These studies have identified two potential links between IT and multifactor productivity growth: IT-induced organizational innovations and network or spillover effects. First, firm-level studies suggest that to benefit from investment in IT, firms must change their workplace and organizational practices (Brynjolfsson and Hitt, 2000; Gera and Gu, forthcoming). These organizational changes include the restructuring of the production process, management systems and employee involvement schemes, and external reorganization emphasizing customer orientation, outsourcing, firm networks and other collaborative arrangements (OECD, 2003). As a result of organizational changes, investment in IT improves production efficiencies of the firms using IT and thus leads to multifactor productivity growth.

Second, IT could be linked to multifactor productivity growth through network or spillover effects. The OECD (2003) argues that the emergence of the Internet in the mid-1990s has expanded the effectiveness of IT and improved communications between producers as well as between producers and consumers. In addition, IT have allowed new businesses and markets to flourish rapidly in areas of new economy.

In this study, we make a number of contributions. First, we examine the issue of whether IT is linked to strong MFP growth in Canada through IT-induced organizational innovation and network or spillover effects. None of the existing studies for Canada has examined this issue. Second, we use data for 122 industries

— the most detailed industry aggregation that is available for productivity analysis — to examine the relationship between IT and productivity growth. Previous studies are restricted to a much broader industry aggregation (e.g. two-digit manufacturing plus one-digit non-manufacturing industries). Third, we examine the hypothesis that human capital and IT are complementary in improving productivity performance in Canadian industries. We also examine the hypothesis that industries that are more open to international competition benefit more from IT investments. It has been argued that to realize potential productivity gains from IT, human capital and competitive pressures are essential.

The rest of the study is organized as follows. In the next section, we provide a brief description of our data sources. In the third section, we examine the sources of output and labour productivity for the Canadian business sector. The fourth section addresses the issue of whether IT is linked to the post-1995 MFP growth acceleration in the business sector. In the fifth section, we ask the question: Do industries that have a larger share of knowledge workers and are more open to international competition benefit more from IT? The last section concludes the study.

Data Sources

DATA FOR OUR STUDY ARE OBTAINED from Statistics Canada's multifactor productivity database, which provides statistics on gross output, intermediate inputs, capital services and labour services for 122 individual industries of the Canadian business sector. Gross output and intermediate inputs in the database are constructed from Statistics Canada annual input-output tables. The measures of capital services and labour services recognize differences in the contributions of workers and capital to output and productivity. Labour input estimates reflect the compositional changes of workers with different educational attainment and experience (for details, see Gu, Kaci, Maynard, and Sillamaa, 2003). Capital input estimates are constructed from data on 28 producible assets plus land and inventories (for details, see Harchaoui and Tarkhani, 2003; and Gellatly, Tanguay, and Yan, 2003). Consequently, the capital input estimates account for substitution between these various assets. For the purpose of this study, capital input is divided into IT and non-IT capital, and labour input into labour input from university-educated workers and from non university-educated workers.

It should be noted that the gross output and intermediate inputs for the 1998-2000 period are estimated from preliminary input-output tables for the period.[2]

Statistics Canada uses the North American Industry Classification (NAICS) for the construction of input-output tables for the year 1997 onward. For the purpose of this project, we have constructed annual input-output tables based on the 1980 Standard Industrial Classification (SIC) for the years 1998, 1999 and 2000. These SIC-based input-output tables provide a time series of industry productivity at the P-level of industry classification) over the period 1981-2000.

Output and Productivity Growth for the Business Sector

IN THIS SECTION, WE EXAMINE THE SOURCES of value-added and labour productivity growth for the total business sector. From a traditional growth accounting technique, the growth in value added can be decomposed into three main sources: contribution of capital input, contribution of labour input, and multi-factor productivity growth. For the purpose of this study, we further allocate the contribution of capital input between IT and non-IT capital inputs. We also allocate the contribution of labour input between university and non-university labour input in order to examine the importance of educational attainment and human capital for economic growth.

The growth accounting technique decomposes value-added growth for the business sector as follows:

$$\begin{aligned} \Delta \ln V \equiv\ & \overline{v}^{IT} \Delta \ln K^{IT} + \overline{v}^{NIT} \Delta \ln K^{NIT} \\ & + \overline{v}^{U} \Delta \ln L^{U} + \overline{v}^{NU} \Delta \ln L^{NU} + MFP \end{aligned} \tag{1}$$

where V is value added for the business sector, K^{IT} is the flow of capital services from investment in IT, K^{NIT} is the flow of capital services from non-IT capital services, L^{U} is labour input from university-educated workers, L^{NU} is labour input from non-university-educated workers, $\overline{v}$ is the share of an input in aggregate nominal value added, averaged over two periods.

Subtracting changes in hours worked $\Delta \ln H$ from both sides of Equation (1), we have the decomposition equation for aggregate labour productivity growth (ALP):

$$\begin{aligned} \Delta \ln(V/H) \equiv\ & \overline{v}^{IT} \Delta \ln(K^{IT}/H) + \overline{v}^{NIT} \Delta \ln(K^{NIT}/H) \\ & + \overline{v}^{U} \left[\Delta \ln Q^{U} + \Delta \ln \left(H^{U}/H \right) \right] \\ & + \overline{v}^{NU} \left[\Delta \ln Q^{NU} + \Delta \ln \left(H^{NU}/H \right) \right] + MFP \end{aligned} \tag{2}$$

Aggregate labour productivity growth in Equation (2) is decomposed into contributions from IT capital deepening, non-IT capital deepening and labour composition (or labour quality), and MFP growth. The contribution of labour composition to aggregate labour productivity growth is further decomposed into contributions from university and non-university workers and compositional shifts between university and non-university workers,

$$\overline{v}^{U}\Delta\ln\left(H^{U}/H\right)+\overline{v}^{NU}\Delta\ln\left(H^{NU}/H\right).$$

Table 1 summarizes the results of a growth accounting decomposition for value-added growth in the Canadian business sector. The decomposition is based on annual observations for the period 1981-2000, as well as sub-periods 1981-88, 1988-95 and 1995-2000. Our choice of the periods for the analysis is based on a number of considerations. The year 1981 is the first year for which Canada's industry output series are comparable to the United States. The year 1988 is approximately the end of the productivity growth cycle during the 1980s in Canada, and 1995 represents the year when the productivity growth revival in Canada started.

Results in Table 1 show that value added rose at an annual rate of 3.18 percent per year in the business sector during the period 1981-2000. Labour input contributed 1.35 percentage points. Capital input contributed 1.19 percentage points. The remaining 0.64 percentage points were due to MFP growth. Over the period 1981-2000, university-educated workers were as significant as non-university-educated workers in their contribution to the value-added growth of the business sector, even though university-educated workers only accounted for about 12 percent of hours worked. Similarly, IT capital services made a significant contribution to the growth in aggregate value-added despite their relatively small share in total capital services. The importance of university-educated workers and IT capital services reflect the fact that they tend to have higher marginal products than non-university-educated workers and non-IT capital services.

Table 1

Sources of Value Added Growth in the Business Sector, 1981-2000 (percentage points per year)

	1981-2000 (1)	1981-88 (2)	1988-95 (3)	1995-2000 (4)	(4) – (3)
Value Added	3.18	3.27	1.84	4.98	3.14
Contribution of Capital Input	1.19	1.14	0.75	1.64	0.89
IT	0.44	0.36	0.34	0.58	0.24
Non-IT	0.75	0.78	0.41	1.06	0.65
Contribution of Labour Input	1.35	1.42	0.52	2.28	1.76
University	0.60	0.44	0.50	0.86	0.36
Non-university	0.75	0.98	0.02	1.42	1.40
Aggregate MFP	0.64	0.72	0.57	1.06	0.49

The value-added growth showed a large increase in the business sector during the second half of the 1990s. Our results in Table 1 show that annual value-added growth rose from 1.84 to 4.98 percent between the periods 1988-95 and 1995-2000. This represents a 3.14 percentage-point increase during these two periods. About half of the output growth revival was due to an increased contribution from labour input, and mostly from non-university-educated workers. Capital deepening from both IT and non-IT was next in importance as a source of output growth revival, contributing 0.89 percentage points. MFP growth was also an important source of the growth acceleration in the Canadian business sector, contributing 0.49 percentage points.

In Table 2, we use equation (2) to decompose aggregate labour productivity growth into three sources: capital deepening, labour quality and MFP growth. Our decomposition results show that three sources made similar contributions to labour productivity growth in the business sector during the period 1981-2000. During that period, labour productivity rose by 1.55 percent per year. Capital deepening contributed 0.54 percentage points. Shifts in labour composition toward more educated and more experienced workers or labour composition contributed 0.37 percentage points. MFP growth accounted for 0.64 percentage points.

Table 2

Sources of Labour Productivity Growth in the Business Sector, 1981-2000 (percentage points per year)

	1981-2000 (1)	1981-88 (2)	1988-95 (3)	1995-2000 (4)	(4) – (3)
ALP Growth	1.55	1.32	1.56	1.91	0.35
Contribution of Capital Deepening	0.54	0.38	0.64	0.40	–0.24
IT	0.39	0.32	0.33	0.48	0.15
Non-IT	0.15	0.06	0.31	–0.08	–0.38
Contribution of Labour Quality	0.37	0.23	0.35	0.45	0.10
University	0.02	0.00	0.02	0.06	0.03
Non-university	0.19	0.15	0.17	0.24	0.07
Reallocation of Hours	0.15	0.08	0.16	0.16	0.00
Aggregate MFP	0.64	0.72	0.57	1.06	0.49

When we allocate the contribution of capital deepening to labour productivity growth between IT and non-IT capital services, we find that IT-capital deepening was more important than non-IT-capital deepening for labour productivity growth in the business sector. We also find that the importance of IT capital for productivity growth increased over the 1981-2000 period. For the 1995-2000 period, all of the productivity contribution from capital deepening was due to IT capital services. The contribution from non-IT capital-deepening was very small for that period.

The revival in output growth of the Canadian business sector in the period 1995-2000 reflects a dramatic increase in hours growth of 2.64 percentage points and a rise in labour productivity growth of 0.76 percentage points. Our decomposition results in Table 2 show that the post-1995 increase in labour productivity growth is entirely due to acceleration in MFP growth. Capital deepening made a small negative contribution to the labour productivity growth revival, which was partially offset by the positive contribution of labour composition.

While overall capital deepening slowed for the business sector after 1995, capital deepening from IT increased, making a positive though small contribution to the post-1995 increase in labour productivity growth in Canada.

Is the Productivity Growth Revival Linked to IT?

IN THIS SECTION, we ask whether the post-1995 MFP growth acceleration of the Canadian business sector is linked to IT use. We proceed in a number of steps. First, we ask how widespread the productivity growth revival is across Canadian industries. If the post-1995 pickup in productivity growth is concentrated in a few industries, IT use is unlikely to constitute the main factor behind the productivity acceleration in the Canadian business sector. During the 1990s, most Canadian industries have increased IT investments as a result of rapid technical progress in IT production and sharp declines in IT investment goods. If IT use is behind the productivity growth acceleration, the acceleration should have occurred in most Canadian industries.

Second, we consider aggregation over industries. In a growth accounting framework, MFP growth in the business sector can be traced to contributions from individual industries. If IT use is linked to the productivity growth revival, most MFP growth revival for the business sector should come from IT-intensive industries.

Third, we use regression analysis to examine the issue of whether IT use is linked to the productivity acceleration. If IT were the driving force behind the MFP revival, the post-1995 productivity acceleration should be positively related to IT use.

Is the Productivity Acceleration Widespread?

We have constructed MFP growth for 122 individual industries of the Canadian business sector over the period 1981-2000. The MFP growth of an industry is calculated as the difference between gross output growth and a share-weighted sum of input growth for capital service, labour service and intermediate inputs (Jorgenson, Ho, and Stiroh, 2002).

Table 3 presents summary statistics regarding MFP and ALP growth for the period 1995-2000 compared to the period 1988-95. Our results in Table 3 show that MFP growth increased in 62 of the 122 industries between the 1988-95 and 1995-2000 periods. These industries include large service industries such as wholesale, retail, communication services and financial services (see Table A1 in the appendix). As such, the industries with accelerating MFP growth accounted for the majority of gross output and hours worked (76.8 percent of total hours and 67.0 percent of gross output in 1995). We conclude that the post-1995 productivity growth acceleration has been pervasive across Canadian industries.

Table 3

Summary Statistics for Post-1995 Changes in Productivity Growth at Individual Industries

	Number of Industries	Hours Share (%), 1995	Output Share(%), 1995
Increase in ALP Growth	63	70.7	57.8
Increase in MFP Growth	62	76.8	67.0
Increase in both ALP and MFP Growth	49	63.7	51.9
Increase in ALP Growth, but not in MFP Growth	14	9.0	6.0
Increase in MFP Growth, but not in ALP Growth	13	13.2	15.1

Note: The total number of industries is 122.

While the productivity growth revival is pervasive across industries, an issue remains as to whether the revival is statistically significant. To address the issue, we use a simple test of changes in mean growth rates across industries.

(3) $$\Delta \ln A_{i,t} = \alpha + \beta \, D + \varepsilon_{i,t}, \text{ with } D = 1 \text{ if } t > 1995, \; D = 0 \text{ otherwise}$$

where $\Delta \ln A_{i,t}$ is annual MFP growth for industry i, t is either years 1981 to 2000 or years 1988 to 2000. The coefficient α shows the mean MFP growth prior to 1995, and β the mean change in MFP growth in the 1995-2000 period compared to either 1981-95 or 1988-95 period.

To ensure the estimated coefficients mirror the aggregate productivity trend, we have estimated Equation (3) using a weighted least square regression. Nominal output was used as weights for the MFP growth regression. Our regression results show a large and statistically significant increase in MFP growth across Canadian industries after 1995. Between the 1988-95 and 1995-2000 periods, MFP growth increased by about 0.3 percentage points per year. The increase is statistically significant at the 5 percent level.

Aggregation over Industries

Our growth decomposition shows that the post-1995 acceleration in labour productivity growth for the business sector is almost entirely attributed to the acceleration in MFP growth. IT capital deepening made little contribution to this rise in labour productivity growth.

While IT capital accumulation was not directly responsible for the recent pickup in labour productivity growth in Canada, it has been suggested that IT may be linked to MFP growth through organizational innovation and spillover or network effects (Gera, Gu, and Lee, 1999; OECD, 2003). IT has allowed firms to adopt more efficient work organization, and improve communication between producers and consumers. This new technology has allowed new businesses and markets to flourish. In addition, IT industries develop, deliver and support products and services at the heart of the technology revolution (Beckstead and Gellatly, 2003). The OECD (2003, p.16) concludes that these additional gains has been important for Australia, Canada and the United States.

Our finding that MFP growth acceleration is pervasive across industries suggests that IT could be an important force behind the MFP growth. In this section, we use the growth accounting technique to examine the contribution of IT-intensive industries to increases in aggregate MFP growth in the 1990s. If IT has a positive effect on MFP growth, most MFP growth acceleration in the Canadian business sector should come from those industries that have invested heavily in IT.

Table 4

Tests of Post-1995 Acceleration of Industry MFP Growth

Dependent Variable: Annual MFP Growth

	1988-2000		1981-2000	
Constant	0.226** (2.41)	–	0.274*** (3.81)	–
Post-1995 Dummy	0.309** (2.13)	0.286** (2.03)	0.262* (1.87)	0.254* (1.86)
Industry Fixed Effects	No	Yes	No	Yes

Note: The coefficient estimates are based on a weighted least square regression nominal output as weights. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

In a growth accounting framework, aggregate MFP growth can be expressed as a weighted sum of industry MFP growth using Domar weights plus terms reflecting the reallocations of resources across industries. The Domar weight in the framework is defined as the ratio of industry gross output to aggregate value added in nominal dollars. We have applied this Domar aggregation to examine the sources of aggregate MFP growth in Canada. The results are shown in Table 5.

In Table 5, we have divided industries into those that are IT-intensive and non-IT-intensive, using the IT share of capital services in 1995. These two groups are defined such that each accounted for about half of the aggregate output for the period 1988-95. There are a total of 33 IT-intensive industries, and the remaining 89 industries are classified as non-IT-intensive. Table A1 in the Appendix provides a list of the 33 IT-intensive industries. Most IT service industries such as wholesale and retail trade, financial services and communication services are classified as IT-intensive industries.

Our results show that IT-intensive industries made little contribution to MFP growth before 1995. Almost all MFP growth of the business sector can be attributed to non-IT-intensive industries for the period 1981-95. However, after 1995, IT-intensive industries were a much more important source of aggregate MFP growth than non-IT-intensive industries. For the period 1995-2000, IT-intensive industries contributed 0.71 percentage points or 66 percent of the aggregate MFP growth.

Table 5

Sources of MFP Growth in the Business Sector

	1981-2000 (1)	**1981-88 (2)**	**1988-95 (3)**	**1995-2000 (4)**	**(4) – (3)**
Aggregate MFP Growth	0.64	0.72	0.57	1.06	0.49
Domar-weighted MFP	0.65	0.72	0.57	1.06	0.49
IT Intensive	0.13	–0.01	0.05	0.71	0.66
Non-IT Intensive	0.52	0.72	0.52	0.34	–0.18
Reallocation of Capital and Labour	0.00	0.00	0.00	0.00	0.01

Table 6

Top 10 Contributors to the Post-1995 MFP Growth Revival in the Business Sector

SIC 1980	Industries	IT Share
113	Retail Trade Industries	0.22
98	Construction	0.16
117	Other Business Services Industries	0.14
67	Motor Vehicle Industry	0.10
114	Finance and Real Estate Industries	0.10
109	Electric Power Systems Industry	0.08
120	Accommodation and Food Services Industries	0.07
107	Telecommunication Carriers Industries	0.06
123	Membership Organisation (excluding religious) & Other Service Industries	0.05
121	Amusement and Recreational Services	0.05

Annual MFP growth of the business sector rose by 0.49 percentage points in the period 1995-2000 relative to 1988-95. Our results show that all of this acceleration is due to the increased MFP growth in IT-intensive industries. As shown in Table 6, 8 of the top 10 contributors to the post-1995 rise in MFP growth are IT-intensive services industries.[3] None of these industries are manufacturing industries that produce IT. This provides evidence in support of the view that IT use has raised MFP growth of the Canadian business sector

The Link Between IT and the Productivity Revival Across Industries

In this section, we address the issue of whether the aggregate MFP growth revival is linked to IT use by examining cross-industry relationship between IT use and MFP growth. If IT is a main factor for faster productivity growth, the industries that are more IT intensive should have larger gains in productivity growth.

Table 7 presents average MFP growth for IT- and non-IT-intensive industries. During the period 1988-95, IT-intensive industries have slower MFP growth than non-IT-intensive industries. This suggests that IT made little contribution to productivity growth in the Canadian business sector before the mid-1990s. After 1995,

Table 7

Productivity Growth by IT Intensity

	Share of Hours	Share of Output	MFP Growth	ALP Growth
1988-1995				
IT Intensive	0.63	0.49	0.05	1.24
Non-IT Intensive	0.37	0.51	0.52	1.92
1995-2000				
IT Intensive	0.66	0.52	0.69	2.65
Non-IT Intensive	0.34	0.48	0.36	1.81
1995-2000 less 1988-1995				
IT Intensive	0.03	0.03	0.63	1.41
Non-IT Intensive	–0.03	-0.03	–0.16	–0.11

Note: Average MFP growth is calculated as a weighted average of MFP growth using nominal gross output as weights. Average ALP growth uses hours worked as weights.

this so-called Solow productivity paradox disappeared in the Canadian business sector. IT-intensive industries have faster MFP growth than non-IT-intensive industries. Between the 1988-95 and 1995-2000 periods, IT-intensive industries showed large gains in MFP growth. In contrast, non-IT-intensive industries showed a slight decline.

We have estimated the correlation between changes in MFP growth during the 1988-95 and 1995-2000 periods across industries against IT share in 1995. We find that there is a positive and statistically significant relationship between MFP growth changes and IT share of capital services across Canadian industries. That is, industries that are more IT intensive had larger increases in MFP growth between these two periods.

While raw correlations are suggestive of a positive relationship between IT and MFP growth, more rigorous evidence can be provided using the following regression equation:

$$\Delta \ln A_{i,t} = \alpha + \beta\, D + \gamma\, IT_{95} + \eta\, D \cdot IT_{95} + \varepsilon_{i,t}\,, \quad \text{with } D = 1 \text{ if } t > 1995,\ D = 0 \text{ otherwise} \tag{4}$$

where $\Delta \ln A_{i,t}$ is annual MFP growth for industry i, IT_{95} is IT share of capital service in 1995, the coefficient γ shows the relationship between IT and productivity growth before 1995, the coefficient η measures the association between IT and post-1995 changes in MFP growth.

The results, shown in Table 8, show there is a positive and statistically significant relationship between IT and productivity growth acceleration across industries. The effects are quite large. Our estimates show that a 0.1 percentage-point increase in IT capital share is associated with a 0.4 percentage-point acceleration in annual MFP growth after 1995. This supports the view that the industries that purchased more IT experienced larger productivity gains later on. Our finding on a positive relationship between IT capital share and MFP growth acceleration provides evidence for the view that IT raised MFP through complementary organizational innovation and spillover or network effects.

Table 8

Regression Results for IT and Productivity Growth

Dependent Variable: Annual MFP Growth

	1988-2000		1981-2000	
Constant	0.515*** (3.28)	–	0.624*** (5.24)	–
IT-Intensity	-1.261** (-2.28)	–	-1.590*** (-3.68)	–
Post-1995 Dummy	-0.433* (-1.78)	-0.502** (-2.13)	-0.542** (-2.32)	-0.593*** (-2.62)
Post-1995 Dummy*IT-Intensity	3.173*** (3.78)	3.366*** (4.15)	3.503*** (4.33)	3.644*** (4.66)
Industry Fixed Effects	No	Yes	No	Yes

Note: The coefficient estimates are based on a weighted least square using nominal output as weights for MFP growth regression. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

Robustness Checks

In this section we provide a number of robustness checks on our finding that IT is linked to MFP growth. First, we check if our finding is robust when we exclude those industries with less reliable productivity measures. Second, we check if our finding is robust when we exclude IT-producing industries. Third, we check if our result is robust to using an alternative measure of IT capital share.

Beckstead, Girard, and Harchaoui (2001) identified a number of Canadian industries that have less reliable productivity measures. These industries include construction, financial and real estate, business services, and other services industries. When we exclude those industries from our MFP growth regression (4), we find a similar result as is shown in Table 9. Our results show that IT is linked to post-1995 MFP growth acceleration across these well-measured Canadian industries. The relationship is statistically significant at the 5 percent level.

IT-producing industries had rapid MFP growth and they were also among the most IT-intensive.[4] When we rerun regression (4) on a sample of industries that exclude the IT-producing industries, we obtain similar results (Table 10).

Table 9

Regression Results for IT and Productivity Growth (on a sample of well-measured industries)

Dependent Variable: Annual MFP Growth

	1988-2000		1981-2000	
Constant	0.717*** (3.82)	–	0.484*** (5.68)	–
IT Intensive	-1.291 (-1.57)	–	-0.032*** (-4.54)	–
Post-1995 Dummy	-0.752*** (-2.61)	-0.750*** (-2.66)	-0.094 (-0.56)	-0.643** (-2.38)
Post-1995 Dummy*IT-Intensity	4.757*** (3.73)	4.644*** (3.73)	0.050*** (3.96)	3.063** (2.56)
Industry Fixed Effects	No	Yes	No	Yes

Note: The coefficient estimates are based on a weighted least square regression using nominal output as weights for MFP growth regression. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

Table 10

Regression Results for IT and Productivity Growth
(on a sample of industries excluding IT-producing industries)

Dependent Variable: Annual MFP Growth

	1988-2000		1981-2000	
Constant	0.589*** (3.81)	–	0.762*** (6.49)	–
IT Intensive	–1.888*** (–3.34)	–	–2.640*** (-5.94)	–
Post-1995 Dummy	–0.442* (–1.85)	–0.498** (–2.13)	–0.615*** (–2.68)	–0.646*** (–2.86)
Post-1995 Dummy*IT-Intensity	3.086*** (3.61)	3.246*** (3.89)	3.839*** (4.64)	3.898*** (4.81)
Industry Fixed Effects	No	Yes	No	Yes

Note: The coefficient estimates are based on a weighted least square regression using nominal output as weights for MFP growth regression. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

Our results above use IT share in capital services as an independent variable. When we use share of IT capital in nominal gross output, we find our results are robust to using this alternative measure of IT capital share (Table 11).

Our empirical specification in equation (4) for examining the relationship between IT and MFP growth puts all the explanatory burden on IT capital share. It is possible that other variables, such as the share of intermediate input in nominal output, are also linked to the acceleration in MFP growth. When we replace IT capital share in Equation (4) by intermediate input share, we find that the new variable is not related to MFP growth (Table 12).[5]

In sum, we find strong and robust evidence that IT is linked the post-1995 MFP growth acceleration across Canadian industries. Our evidence supports the view that IT raised MFP in Canada through IT-induced organizational innovation and network or spillover effects.

Table 11

Regression Results for IT and Productivity Growth
(using share of IT capital service in nominal output as independent variable)

Dependent Variable: Annual MFP Growth

	1988-2000		**1981-2000**	
Constant	0.375*** (3.32)	–	0.484*** (5.68)	–
IT Service-output ratio	–0.021** (-2.36)	–	–0.032*** (–4.54)	–
Post-1995 Dummy	–0.015 (–0.09)	–0.034 (–0.20)	–0.094 (-0.56)	–0.150 (–0.92)
Post-1995 Dummy*IT-output Ratio	0.039*** (2.99)	0.043*** (3.35)	0.050*** (3.96)	0.054*** (4.43)
Industry Fixed Effects	No	Yes	No	Yes

Note: The coefficient estimates are based on a weighted least square regression using nominal output as weights for MFP growth regression. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

Table 12

Regression Results for Intermediate Inputs and Productivity Growth

Dependent Variable: Annual MFP Growth

	1988-2000		**1981-2000**	
Constant	0.348 (1.36)	–	0.855*** (4.43)	–
Intermediate Input-output Ratio	–0.002 (–0.51)	–	–0.011*** (–3.25)	–
Post-1995 Dummy	0.281 (0.71)	0.336 (0.88)	–0.226 (–0.60)	–0.071 (–0.19)
Post-1995 Dummy*Inter. Input-output Ratio	0.001 (0.08)	–0.001 (–0.14)	0.010 (1.38)	0.006 (0.96)
Industry Fixed Effects	No	Yes	No	Yes

Note: The coefficient estimates are based on a weighted least square regression using nominal output as weights for MFP growth regression. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

Our finding for Canada is consistent with the one for the United States that is reported in Basu et al. (2003). Basu et al. (2003) find that IT use is linked to MFP growth in the U.S. business sector during the 1990s. They interpret this as evidence that IT has raised multifactor productivity in the United States through purposeful co-invention in organizational capital and externalities associated with IT investments.

Stiroh (2002a) has also examined the relationship between IT and MFP growth revival and finds that IT is not related to the acceleration in MFP growth across the U.S. manufacturing industries. However, most IT investments are in non-manufacturing industries such as finance, insurance and real estate, and wholesale and retail trade. His focus on manufacturing industries may have missed the biggest impact from IT.

The Role of Human Capital and Trade Openness for Productivity Growth

OUR RESULTS SHOW that IT is linked to the post-1995 rise in MFP growth in the Canadian business sector. In this section, we ask whether there are other industry characteristics that are related to the MFP acceleration. Previous studies have argued that firms must have skilled workers to realize the productivity potential from new technologies such as IT. That is, skilled workers are complementary to IT in improving productivity performance (Jorgenson, Ho, and Stiroh, 2002; Bresnahan, Brynjolfsson, and Hitt, 2002). It can be also argued that the industries that face greater international competition are more likely to adopt changes in workplace practices to enhance gains from IT. Indeed, Caselli and Coleman II (2001) find that countries that are more open to international trade tend to have faster adoption of computers.

To examine the role of human capital in raising productivity gains of IT, we extend Equation (4) with an additional variable — the share of university workers (measured in 1995) and its interaction term with IT intensity (also measured in 1995). The results are shown in Table 13. The positive coefficient on the interaction term between IT capital share and university-educated worker share suggest that the industries that are both more IT intensive and more skill intensive had larger gains in productivity growth after 1995. The effects are quite large. Our estimates show that a 0.1 percentage-point increase in IT capital share and university worker share is associated with a 0.2 percentage-point acceleration in annual MFP and labour productivity growth in the 1995-2000 period in comparison

Table 13

Regression Results for IT, Human Capital and Productivity Growth

Dependent Variable: Annual MFP Growth

	1988-2000	**1981-2000**
Post-1995 Dummy	0.829** (2.09)	0.457 (1.19)
Post-1995 Dummy*IT-Intensity	2.139 (1.28)	2.494 (1.54)
Post-1995 Dummy*University	–12.41*** (–4.98)	–9.573*** (–4.00)
Post-1995 Dummy*IT-Intensity*University	18.21*** (2.84)	14.60** (2.35)

Note: The coefficient estimates are based on a weighted least square regression using nominal output as weights for MFP growth regression. All regressions include industry fixed effects. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

with the 1988-95 period. This is consistent with the view that IT and skilled workers are complementary in improving productivity performance.

Finally, we examine the issue of whether industries that are more open to international trade have larger productivity gains from IT. Baldwin and Gu (2003) find that export orientation is related to growth and success among Canadian manufacturing plants. As trade data are not available for non-manufacturing industries at our level of industry detail, we restrict our analysis to a sample of manufacturing industries. The results are shown in Table 14.

In Table 14, trade openness is defined as the ratio of exports plus imports to nominal gross output in 1995. In contrast to our results for the business sector, there is no evidence that MFP accelerated after 1995 for the manufacturing industries. The positive coefficient on the interaction term of IT intensity and trade openness suggests that the industries that are more open to international trade have larger gains in productivity growth in the 1995-2000 period. The coefficient estimate is statistically significant at the 10 percent level.[6]

Table 14
Regression Results for IT, Trade Openness and Productivity Growth (on a sample of manufacturing industries)

Dependent Variable: Annual MFP Growth

	1988-2000	**1981-2000**
Post-1995 Dummy	0.662 (0.81)	0.357 (0.47)
Post-1995 Dummy*IT-intensity	–4.794 (–1.15)	–1.631 (–0.42)
Post-1995 Dummy*Trade	–0.874 (–1.25)	–0.376 (–0.58)
Post-1995 Dummy*IT-intensity*Trade	5.082* (1.59)	1.606 (0.54)

Note: The coefficient estimates are based on a weighted least square regression nominal output as weights for MFP growth regression. All regressions include industry fixed effects. t-statistics are in parentheses. One asterisk denotes statistical significance at the 10-percent level, two asterisks denote the 5-percent level, and three asterisks the 1-percent level.

Conclusion

IN THIS STUDY, WE HAVE EXAMINED whether the post-1995 acceleration in productivity growth in the Canadian business sector is linked to information and communications technologies. Our main findings are as follows.

First, our results show that the pickup in labour productivity growth in the Canadian business sector is almost entirely due to the acceleration in MFP growth. Capital deepening was not a contributing factor to the labour productivity growth revival. However, capital deepening from IT increased after 1995, making a positive though small contribution to the post-1995 labour productivity growth acceleration in Canada. Our results for Canada are in sharp contrast to the results for the United States. In the United States, both rapid IT capital deepening and MFP growth acceleration made important contributions to the labour productivity growth revival during the 1990s.

Second, while IT capital deepening made little direct contribution to the labour productivity growth revival in Canada during the 1990s, we find that IT is linked to the MFP growth acceleration in Canada through network and spillover effects.

IT has allowed firms to adopt a more efficient work organization and improve communication between producers and consumers. A number of findings support this view. First, the MFP growth acceleration was pervasive across industries. The industries that experienced MFP acceleration in the 1990s accounted for more than 70 percent of output. Second, all MFP growth acceleration in the 1990s was from IT-intensive industries. Eight of the top ten contributors to the MFP growth acceleration are IT-intensive service industries including: retail trade, communication services, financial services and business services. Third, more IT-intensive industries showed larger MFP growth acceleration in the 1990s than less IT-intensive industries. These findings also support the view in Robidoux and Wong (2003) that the post-1995 productivity growth acceleration that occurred in Canada is a real phenomenon and not only a cyclical one. If the productivity growth acceleration in Canada was due to cyclical forces, these cyclical forces would have to be concentrated in IT-intensive industries for this to be the whole story.[7]

Third, consistent with the view that knowledge workers are complementary to IT, we find that industries that have a larger share of knowledge workers have larger productivity gains from IT. We also find some evidence that manufacturing industries that are more open to international trade have larger productivity gains from IT.

Endnotes

1 The two other studies in this volume have also focused on the distinction between IT use and IT production (Ho, Rao, and Tang, 2003; Harchaoui, Tarkhani, and Khanam, 2003).

2 These tables were constructed in the spring of 2003.

3 Two exceptions are construction and motor vehicles industries.

4 IT-producing industries include communications and other electronic equipment; office, store and business machines; and telecommunication carriers industries.

5 When we introduce the intermediate input and IT shares in a same equation, we find that the coefficient on the interaction term of IT share and the post-1995 dummy remains positive and statistically significant at the 5 percent level. The coefficient on the interaction of intermediate input share and post-1995 dummy is not significant at the 10 percent level for the period 1988-2000. However, for the period

1981-2000, the coefficient on the interaction of intermediate input share and post-1995 dummy is positive and statistically significant at the 5 percent level.

6 For manufacturing industries, we have run a regression that includes both the interaction of trade openness and IT and the interaction of skilled worker share and IT share. We find the coefficient on the former is positive and statistically significant at the 5 percent level, suggesting a complementary relationship between IT and skilled workers in Canadian manufacturing industries. The coefficient on the interaction of trade openness and IT share is positive. But it is no longer statistically significant at the 10 percent level.

7 Stiroh (2002b) made a similar argument against the view that the productivity revival in the United States during the 1990s is not a real phenomenon but only a cyclical one.

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Bibliography

Armstrong, P., T.M. Harchaoui, C. Jackson, and F. Tarkhani. "A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communications Technologies." *Economic Analysis Research Papers*, 11F0027MIE2002001, Statistics Canada, 2002. The study is also published in *Monthly Labor Review*, 2003.

Baldwin, J.B., and W. Gu. "Export-market Participation and Productivity Performance in Canadian Manufacturing." *Canadian Journal of Economics*, 2003.

Basu, S., J.G. Fernald, N. Oulton, and S. Srinivasan. "The Case of the Missing Productivity Growth: or, Does Information Technology Explain Why Productivity Accelerated in the United States but not the United Kingdom?" Paper presented for the 37th annual Canadian Economic Association Meeting, Ottawa, Canada, 2003.

Beckstead, D., and G. Gellatly. "The Growth and Development of New Economy Industries." In *The Canadian Economy in Transition,* Statistics Canada Catalogue No.11-622 (002), 2003.

Beckstead, D., A. Girard, and T.M. Harchaoui. "Quality Rating of Productivity Estimates and Related Data." In *Productivity Growth in Canada*, Statistics Canada Catalogue No. 15-204, 2001.

Bresnahan, T.F., E. Brynjolfsson, and L. Hitt. "Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence." *Quarterly Journal of Economics* 117, 1 (2002): 339-376.

Brynjolfsson, E., and L. Hitt. "Beyond Computation: Information Technology, Organizational Transformation and Business Performance." *Journal of Economic Perspectives* 14, 4 (2000): 23-48.

Caselli, F., and W. Coleman II. "Cross-country Technology Diffusion: The Case of Computers." *American Economic Review* 91, 2 (2001): 328-335.

Colecchia, A., and P. Schreyer. "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries." *Review of Economic Dynamics* 5, 2 (April 2002): 408-443.

Crawford, A. "Trends in Productivity Growth in Canada," *Bank of Canada Review*, (Spring 2002): 19-32.

Faruqui, U., W. Gu, M. Kaci, M. Laroche, and J.-P. Maynard. "Differences in Productivity Growth: Canada-U.S. Business Sectors, 1987-2000." *Monthly Labor Review* 126, 4 (April 2003): 16-29, Washington (D.C.): Bureau of Labor Statistics.

Gellatly, G., M. Tanguay, and B. Yan. "An Alternative Methodology for Estimating Economic Depreciation: New Results from Using a Survival Model." In *Productivity Growth in Canada - 2002*. Edited by J.B. Baldwin and T.M. Harchaoui, Statistics Canada Catalogue No. 12-204, 2003.

Gera, S., and W. Gu. "The Effect of Organizational Innovation and Information Technology on Firm Performance." *Economic Analysis Research Papers*, 11F0027MIE2002001, Statistics Canada. Forthcoming.

Gera, S, W. Gu, and F.C. Lee. "Information Technology and Labour Productivity Growth: An Empirical Analysis for Canada and the U.S." *Canadian Journal of Economics* 32, 2 (1999): 384-407.

Gu, W, M. Kaci, J.-P. Maynard, and M. Sillamaa. "The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin, and T.M. Harchaoui, Statistics Canada Catalogue No. 15-204-XPE, 2003.

Harchaoui T.M., and F. Tarkhani. "A Comprehensive Revision of the Capital Input Methodology for Statistics Canada Multifactor Productivity." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin, and T.M. Harchaoui, Statistics Canada Catalogue No. 15-204-XPE, 2003.

Harchaoui, T.M., F. Tarkhani, and B. Khanam. "Information Technology and Economic Growth in the North American Private Business Sector." Paper presented at the 37th annual Canadian Economic Association Meeting, 2003.

Ho, M., S. Rao, and J. Tang. "The Impact of ICT on Economic and Productivity Growth at the Industry Level: A Canada–U.S. Comparison." Paper presented at the 37th annual Canadian Economic Association Meeting, 2003.

Jorgenson, D.W., M.S. Ho, and K.J. Stiroh. "Growth of U.S. Industries and Investment in Information Technology and Higher Education." Harvard University, 2002. Mimeo.

OECD. *The Sources of Economic Growth in OECD Countries*, Paris, 2003.

Pilat, D., and F.C. Lee. "Productivity Growth in ICT-Producing and ICT-Using Industries: A Source of Growth Differentials in the OECD?" *OECD STI Working Papers*, No. 2001/4, 2001.

Rao, S., and J. Tang. "The Contribution of ICT to Productivity Growth in Canada and the United States in the 1990s." *International Productivity Monitor* 3 (Fall 2001): 3-18.

Robidoux, B., and B. Wong. "Has Trend Productivity Growth Increased in Canada?" Department of Finance, Canada, 2003. Mimeo.

Stiroh, K.J. "Are ICT Spillovers Driving the New Economy?" *Review of Income and Wealth* 48, 1 (2002a): 33-57.

———. "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?" *American Economic Review* 92, 5 (2002b): 1559-1576.

Appendix

Table A1

List of IT-intensive Industries

Industry	**IT share of Capital Service in 1995**
Educational Service Industries	0.7915
Membership Org. (excl. religious) and Other Service Industries	0.7236
Other Business Services Industries	0.6448
Telecommunication Carriers Industries	0.6447
Amusement and Recreational Services	0.4854
Vegetable Oil Mills (except corn oil)	0.4457
Office, Store and Business Machine Industries	0.3870
Telecommunication Broadcasting Industry	0.3803
Water Systems and Other Utility Industries N.E.C.	0.3709
Plastic and Synthetic Resin Industry	0.3644
Finance and Real Estate Industries	0.3575
Postal and Courier Service Industries	0.3545
Major Appliances Industries (electric and non-electric)	0.3212
Rubber Products Industries	0.3205
Communication and Other Electronic Equipment Industries	0.3169
Industrial Chemicals Industries N.E.C.	0.3146
Retail Trade Industries	0.3121
Other Transport Services	0.3112
Communication and Energy Wire and Cable Industries	0.3059
Refined Petroleum and Coal Products Ind.	0.3010
Record Player, Radio and Television Receiver Industries	0.2868
Wholesale Trade Industries	0.2762
Other Electrical and Electronic Product Industries	0.2661
Other Manufacturing Industries	0.2616
Printing and Publishing Industries	0.2610
Insurance Industries	0.2530
Other Personal Service Industries	0.2492
Other Health and Social Service Industries	0.2398
Accommodation and Food Services Industries	0.2382
Air Transport and Related Service Industries	0.2324
Electric Power Systems Industry	0.2294
Gas Distribution Systems Industry	0.2176
Platemaking, Typesetting and Bindery Industries	0.2157

Sources of Output Growth in Canadian and U.S. Industries in the Information Age

4

Mun S. Ho, Someshwar Rao & Jianmin Tang

Abstract

IN THIS STUDY, WE COMPARE AND CONTRAST the sources of economic and labour productivity growth in Canadian and U.S. industries, using newly developed and comparable data for 34 industries covering 1981-2000. We focus on information technology (IT), as both outputs and inputs. Our research shows that output growth in the United States and its acceleration in the second half of the 1990s were driven largely by the accumulation of IT capital and the increased use of university trained workers. In contrast, the growth in Canada was mainly due to the accumulation of non-IT capital and the increased use of non-university labour. The resurgence of the U.S. economy was relatively more concentrated in IT-producing industries while in Canada it was widespread across industries. The contribution of IT capital deepening to labour productivity growth in Canada during the second half of the 1990s was small, but it was the driving force behind the labour productivity growth revival in the United States and its impact was widespread across U.S. industries. Finally, in both countries, IT capital had its largest impact in IT-producing industries, followed by IT-using industries.

Introduction

THE ACCELERATION IN OUTPUT GROWTH in the second half of the 1990s compared to the first half in Canada and the United States has generated a great deal of interest and comment, including the general press. Many have pointed to the rapid growth of investment in information technology (IT) as an important factor for this economic revival. The growth in IT investment has been fuelled largely by the unprecedented decline in the real prices of information technology equipment and software, which in turn is due to the extraordinary pace of innovation and productivity growth in industries that produce them. Meanwhile, the high-tech investment boosted the demand for education and skills which are essential to their effective use. The proportion of workers with university degrees increased significantly.[1] A consensus, while not unanimous, has emerged from recent growth studies that the increased investments in IT and human capital are playing a major role in economic growth and labour productivity growth in both countries.[2]

However, the size of the impact of the two factors is by no means uniform across countries or industries. Stiroh (2002) shows that while IT investments affected many industries in the United States, the degree to which productivity growth is affected is different across industries. Differences in educational attainment also occur across industries, as shown by Jorgenson, Ho, and Stiroh (2002). Similar developments are taking place in Canada, but there are two significant differences between the two countries. First, Canada is less affected by the IT development than the United States — the size of IT-producing industries is small, and Canada invests less in IT in terms of investment to GDP ratio or IT investment intensity (Rao and Tang, 2001; Harchaoui, Tarkhani, Jackson, and Armstrong, 2002). Second, a smaller portion of the labour force in Canada has university education or higher, although the gap narrowed slightly during the second half of the 1990s (Rao, Tang, and Wang, 2002). We shall discuss these differences in this study.

The resurgence of growth in output, labour productivity, and total factor productivity in the United States since 1995 is remarkable. As shown later in this study, the output of the aggregate business sector in the United States grew at 4.5 percent per year during the second half of the 1990s compared to 2.6 percent in the first half. Many authors have attributed a key role to IT for this revival. Of the 4.5 percent growth, IT capital contributed 1.2 percentage points even though it accounts for less than 10 percent of capital input [e.g. Jorgenson, Ho and Stiroh (2002) and Oliner and Sichel (2000)]. The acceleration in output growth was even bigger in Canada, increasing from 2.1 percent per year to 5.0 percent. In Canada, the IT capital is also playing an increasingly significant role in aggregate output growth.

However, when compared to the United States, the improvement in labour productivity growth (output per hour) in the Canadian business sector was fairly modest despite greater acceleration in output growth. In the United States, labour productivity growth increased from 1.0 percent per year during 1988-95 to 2.3 percent during 1995-2000, while Canadian productivity growth increased from 1.6 percent to 1.9 percent. In addition, the sources of labour productivity growth were different in the two countries. In the United States, the contribution from IT capital rose from 0.5 to 1.0 percentage points, while in Canada it merely increased from 0.3 to 0.5 percentage points. These differences are replicated to some extent at the detailed industry level.

Our main objective in this study is to provide an in-depth study of the role of IT revolution in these recent economic and productivity growth trends in Canada. By using comparable data and methodology, we also compare and contrast the Canadian findings with the U.S. experience, and explore possible reasons for the differences in trends in the two economies. In particular, we examine the industry impact of IT and higher education on output and labour productivity growth in both countries. By disaggregating total capital into IT and non-IT capital and by separating labour input into university and non-university education, we examine the reasons for differences in economic and labour productivity growth across industries in the two countries. Two specific questions are addressed. First, are differences in industry output and productivity growth between Canada and the United States linked to IT and higher education? Second, is the difference in performance widespread, or concentrated just in IT-producing and heavy IT-using industries?

Using newly developed data covering the 1981-2000 period, we examine and compare the sources of economic and productivity growth in the two countries for a set of 34 industries that are specially grouped to focus on IT and to do international comparisons. The concordance and industrial classification codes for both Canada and the United States are listed in Table 1. Most of the sectors are the familiar two-digit ones, but some industries are further disaggregated. For example, computer is separated from other machinery; communications and electronic equipment from other electrical equipment; and business services (including software), health and education from other services.[3]

Given our focus on IT, we divide capital input into IT (computer equipment, communication equipment and software) and non-IT (structures, other machinery and equipment, inventories and land). Although IT capital is only a small share of total capital (less than 5 percent of the stock in the United States in 2001), it is growing rapidly. We disaggregate labour input into university and non-university educated types. On the output side, to measure the impact of IT, following van Ark, Inklaar, and McGuckin (2003), we group the 34 industries into three major groups — IT-producing, IT-intensive using and non-IT using industries. To determine whether an industry is an intensive user of IT or not, they used the share of IT capital in total capital input in U.S. industries from Stiroh (2002). The IT-producing industries are: computers; communication and electronic equipment; and communication services. The first two are IT-manufacturing industries and the last is an IT service producing industry.[4] The IT-intensive using industries (hereafter abbreviated as IT-using industries) are: machinery excluding computers; electrical equipment; other transportation equipment; printing and publishing; miscellaneous manufacturing; wholesale trade; retail trade; finance, insurance and real estate (FIRE); and business services. The remaining 22 industries in Table 1 are categorized as non-IT industries.

Our paper is a product of the joint research by Industry Canada, Statistics Canada and Jorgenson Associates.[5] An earlier study, Jorgenson and Lee (2001), quantified the sources of output and productivity growth in Canada and the United States by developing comparable data for Canada, using the same methodology. Two of the studies in this monograph presented detailed industry comparisons of trends of output, inputs and productivity (Gu and Ho, 2000) and productivity levels (Lee and Tang, 2000) in the two countries. In the present study, we follow the framework of Gu and Ho (2000), focusing on IT and highly educated labour. [6]

In the next section, entitled *Empirical Framework*, we set up a framework for examining the sources of output and labour productivity growth at the industry level. In the same section, we also outline the framework for analyzing the contribution of individual industries to aggregate output and aggregate labour productivity growth. In the section entitled *Data and Measurements Issues*, we describe the data used. In the section entitled *Growth Accounting Results*, we report the results on sources of output and labour productivity growth in individual industries in the two countries. In this section, we also compare the performance of the two countries, and give the sources of aggregate output and labour productivity growth for both countries. We give a summary of the key findings in the concluding section.

Table 1

List of Industries in the Canadian and U.S. Business Sectors

Industry			**Canada – Industrial Classification, SIC 1980**	**United States – Industrial Classification, SIC 1987**
1	Agriculture	Agriculture, Forestry and Fisheries	011-023, 031-033	01,02,07-09
2	Non-energy Mining	Non-Energy Mining	061, 062, 081-082, 091-092	10,14
3	Coal Mining	Coal Mining	063	12
4	Crude Petroleum	Crude Petroleum and Natural Gas	071	13
5	Construction	Construction	401-449	15-17
6	Wood and Furniture	Lumber, Wood, Furniture	041, 051, 251-259, 261-269	24-25
7	Non-metallic	Stone, Clay and Glass	351-359	32
8	Primary Metal	Primary Metal	291-299	33
9	Fabricated Metal	Fabricated Metal	301-306, 309	34
10	Machinery	Machinery Excluding Computers	307, 308, 311-319	35 except 357
11	Computers	Computers and Office Equipment	336	357
12	Electrical Equipment	Other Electrical Equipment	331-334, 337-339	36 except (366-367)
13	Electronic Equipment	Communication and Electronic Equipment	335	366-367
14	Motor Vehicles	Motor Vehicles	323-325	371
15	Other Trans. Equipment	Other Transportation Equipment	321, 326-329	372-379
16	Misc. Manufacturing	Miscellaneous Manufacturing	391-399	38-39
17	Food and Tobacco	Food and Tobacco	100-114, 121-122	20-21
18	Textiles	Textiles, Apparel, Leather	1711-1719, 181-199, 243-249	22-23, 31
19	Paper and Allied	Paper and Allied	271-279	26

Table 1 (cont'd)

List of Industries in the Canadian and U.S. Business Sectors

Industry			**Canada – Industrial Classification, SIC 1980**	**United States – Industrial Classification, SIC 1987**
20	Printing	Printing and Publishing	281-284	27
21	Chemicals	Chemicals	371-379	28
22	Petroleum Refining	Petroleum Refining	361-369	29
23	Rubber and Plastics	Rubber and Plastics	151-159, 161-169	30
24	Transportation	Transportation and Warehousing	451-479, 484	40-47
25	Communications	Communications	481-483	48
26	Electric Utilities	Electric Utilities	491	491, %493
27	Gas Utilities	Gas Utilities	492	492, %493
28	Wholesale Trade	Wholesale Trade	501-599	50-51
29	Retail Trade	Retail Trade	601-692	52-59
30	FIRE	Finance, Insurance and Real Estate (Rental)	70-74, 7511-7512, 759, 76	60-67
31	Business Services	Business Services	771-779	73, 81
32	Health Services	Health and Social Services, Private	862-869	801-809, 83
33	Education, Private	Education, Private	851-852, 854-859	82
34	Other Services	Other Services	493-499, 911-999	494-497, 70-72, 75-79, 84-87, 89

Empirical Framework

FOLLOWING JORGENSON, GOLLOP, AND FRAUMENI (1987) and Gu and Ho (2000), we use the growth accounting framework to examine the sources of labour productivity growth of industries. This framework has been widely used to study the sources of economic growth. Unlike previous studies, however, our study concentrates on IT and human capital. We begin at the industry level and then proceed to describing the decomposition of aggregate growth.

Industry Analysis

We assume that the production function for industry i has the form:

$$Y_i = A_i \cdot f(K_i^{IT}, K_i^{NIT}, L_i^{BA}, L_i^{NBA}, M_i), \quad (1)$$

where Y_i is annual industry gross output; K_i^{IT} and K_i^{NIT} are IT and non-IT capital inputs; L_i^{BA} and L_i^{NBA} are labour inputs with and without at least a B.A. degree; M_i is total intermediate input; and A_i is the augment factor of the input function, often referred as multifactor productivity (MFP).[7]

Under the assumption of constant returns to scale and competitive product and factor markets, the translog index of productivity growth for industry i is :

$$\begin{aligned}\Delta \ln A_i &= \Delta \ln Y_i - \overline{v}_{IT,i}\Delta \ln K_i^{IT} - \overline{v}_{NIT,i}\Delta \ln K_i^{NIT} \\ &\quad - \overline{v}_{BA,i}\Delta \ln L_i^{BA} - \overline{v}_{NBA,i}\Delta \ln L_i^{NBA} - \overline{v}_{m,i}\Delta \ln M_i\ ,\end{aligned} \quad (2)$$

where $\Delta \ln X = \ln X_t - \ln X_{t-1}$, and $\overline{v}_{X,i}$ is the two-period average income share of input X in the value of gross output, and the sum of income shares of all inputs equals to one.[8] For example,

$$v_{m,i,t} = \frac{p_{i,t}^{M} M_{i,t}}{p_{i,t}^{Y} Y_{i,t}}\ ;\ \overline{v}_{m,i,t} = \tfrac{1}{2}(v_{m,i,t-1} + v_{m,i,t})\ ,$$

where the $p's$ denote the corresponding prices.

We shall also be examining the growth in output per hour worked, or labour productivity growth. By rewriting Equation (2), the translog index of labour productivity growth for industry *i* may be expressed as:

$$\text{(3)} \quad \begin{aligned} \Delta \ln y_i &= \Delta \ln A_i + \bar{v}_{IT,i} \Delta \ln k_i^{IT} + \bar{v}_{NIT,i} \Delta \ln k_i^{NIT} \\ &\quad + \bar{v}_{BA,i} \Delta \ln l_i^{BA} + \bar{v}_{NBA,i} \Delta \ln l_i^{NBA} + \bar{v}_{m,i} \Delta \ln m_i \ , \end{aligned}$$

where the lower case variables denote the corresponding quantity per hour worked. Denoting the total hours worked by H_i, we have:

$y_i = Y_i / H_i$ is gross output labour productivity;
$k_i^{IT} = K_i^{IT} / H_i$ is IT capital intensity;
$k_i^{NIT} = K_i^{NIT} / H_i$ is non-IT capital intensity;
$l_i^{BA} = L_i^{BA} / H_i$ is labour quality improvement due to university labour input;
$l_i^{NBA} = L_i^{NBA} / H_i$ is labour quality improvement due to non-university labour input; and
$m_i = M_i / H_i$ is intermediate input intensity.

Labour productivity growth is equal to the change in MFP plus the weighted sum of changes in intensity of inputs. The change in capital input intensity is often referred to as *capital deepening*. Under this framework, the change in MFP is measured as the residual of labour productivity growth net contributions from capital deepening, labour quality improvement and an increase in intermediate input intensity.[9] Because of the constant return to scale assumption, MFP derived from Equations (2) and (3) will be identical.

Each of the inputs in Equation (1) is an aggregate of many components. Intermediate input consists of energy, non-energy materials and purchased services.[10] Capital includes machinery and equipment, structures, land and inventories. Labour is cross-classified by sex, age and education. Capital and labour inputs are aggregated using a *constant quality* method. Capital inputs are quantity indexes of capital stocks, using rental prices as weights. The difference of the growth rates of capital input and stock is the growth rate of industry capital quality (or change in the composition index). Similarly, labour inputs are quantity indexes of hours worked using labour compensation as weights. The differences in growth rates between labour inputs and hours are the growth rates of labour quality for university and non-university labour.[11] The quality adjustment is consistent with the production theory, which suggests that the marginal product of an input should generally equal its price. Our approach here of separating IT capital from non-IT will generate slower changes in capital quality indexes than previous work which employs only one capital input index. A detailed discussion of measuring constant quality capital and labour inputs is given in Appendix A.

Industrial Contributions to Aggregate Productivity Growth

In order to provide an overall view of the entire business sector, in this section we describe a framework to aggregate across industries.[12] The existence of an aggregate production function requires strong assumptions. Here we follow the production possibility frontier approach in Jorgenson, Ho, and Stiroh (2002), which relaxes the assumptions of identical industry value-added functions.

Aggregate value added is defined as a translog index over industry value added:[13]

(4) $$\Delta \ln V = \sum_{i=1}^{34} \tilde{w}_i \Delta \ln V_i ,$$

where $\tilde{w}_i$ is the two-period average share of industry nominal value added in aggregate value added:

$$w_{it} = \frac{p_{it}^V V_{it}}{\sum_j p_{jt}^V V_{jt}} .$$

The value added of industry i is defined as an index of gross output less intermediate inputs:

(5) $$\Delta \ln V_i = \frac{1}{\overline{v}_{v,i}} \left[\Delta \ln Y_i - \left(1 - \overline{v}_{v,i}\right) \Delta \ln M_i \right],$$

where $\overline{v}_{v,i}$ is the two-period average share of nominal value added in nominal gross output in industry i.

The production function for aggregate value added is written as:

(6) $$V = A \cdot f(K^{IT}, K^{NIT}, L^{BA}, L^{NBA}) ,$$

where K^{IT} and K^{NIT} are aggregate IT and non-IT capital inputs; L^{BA} and L^{NBA} are aggregate university and non-university labour inputs; and A is aggregate MFP.

As in the industry framework, under the assumption of constant returns to scale and competitive product and factor markets, the translog index of aggregate MFP growth is:

(7) $$\Delta \ln A = \Delta \ln V - \overline{v}_{IT} \Delta \ln K^{IT} - \overline{v}_{NIT} \Delta \ln K^{NIT} - \overline{v}_{BA} \Delta \ln L^{BA} - \overline{v}_{NBA} \Delta \ln L^{NBA},$$

where $\overline{v}_X$ is the two-period average income share of input X in the value of aggregate value added, and the sum of income shares of all factor inputs equals 1.

Each aggregate input is defined as a translog index over the industry input. For example, IT capital input is:

(8) $$\Delta \ln K^{IT} = \sum_{i=1}^{34} \tilde{w}_{IT,i} \Delta \ln K_i^{IT},$$

where $\tilde{w}_{IT,i}$ is the two-period average share of industry IT capital income in aggregate IT capital income.[14]

Let $H_t = \sum_i H_{i,t}$ denote the aggregate hours worked. Rewriting Equation (7) in terms of per hour worked intensities, the translog index of labour productivity growth at the aggregate level is:

(9) $$\Delta \ln LVP = \Delta \ln A + \overline{v}_{IT} \Delta \ln k^{IT} + \overline{v}_{NIT} \Delta \ln k^{NIT} + \overline{v}_{BA} \Delta \ln l^{BA} + \overline{v}_{NBA} \Delta \ln l^{NBA},$$

where the lower case variables denote the corresponding quantities per hour worked.

$LVP_t = V_t / H_t$ is aggregate value added per hour worked;
$k^{IT} = K^{IT}/H$ is aggregate IT capital intensity;
$k^{NIT} = K^{NIT}/H$ is aggregate non-IT capital intensity;
$l^{BA} = L^{BA}/H$ is labour quality improvement due to aggregate university labour input; and

$l^{NBA} = L^{NBA} / H$ is labour quality improvement due to aggregate non-university labour input.

We also define industry value added per hour worked as:

$$LVP_{it} = V_{it} / H_{it} .$$

This should be distinguished from gross output per hour defined in Equation (3).

With the above pieces, we can now describe the decomposition of aggregate productivity into the industry contributions. Subtracting hours from both sides of Equation (4), we get the relation between aggregate labour productivity and industry productivity:

$$\Delta \ln LVP = \sum_{i=1}^{34} \tilde{w}_i \Delta \ln LVP_i + \left(\sum_{i=1}^{34} \tilde{w}_i \Delta \ln H_i - \Delta \ln H \right). \tag{10}$$

The first term is industry contributions to the aggregate labour productivity and the second term is the reallocation of hours across industries.

The relation between aggregate and sectoral MFP is derived by multiplying both sides of the industry MFP equation [Equation (2)] by the industry share of value added, $\tilde{w}_i$, dividing by the share of value added in industry output, $v_{v,i}$ and summing over all industries. Then substituting Equations (4), (5), and (7) we get:

$$\begin{aligned} \Delta \ln A = & \sum_{i=1}^{34} \frac{\tilde{w}_i}{\overline{v}_{v,i}} \Delta \ln A_i \\ & + \left(\sum_{i=1}^{34} \frac{\tilde{w}_i}{\overline{v}_{v,i}} \overline{v}_{IT,i} \Delta \ln K_{IT,i} - \overline{v}_{IT} \Delta \ln K_{IT} \right) \\ & + \left(\sum_{i=1}^{34} \frac{\tilde{w}_i}{\overline{v}_{v,i}} \overline{v}_{NIT,i} \Delta \ln K_{NIT,i} - \overline{v}_{NIT} \Delta \ln K_{NIT} \right) \\ & + \left(\sum_{i=1}^{34} \frac{\tilde{w}_i}{\overline{v}_{v,i}} \overline{v}_{BA,i} \Delta \ln L_{BA,i} - \overline{v}_{BA} \Delta \ln L_{BA} \right) \\ & + \left(\sum_{i=1}^{34} \frac{\tilde{w}_i}{\overline{v}_{v,i}} \overline{v}_{NBA,i} \Delta \ln L_{NBA,i} - \overline{v}_{NBA} \Delta \ln L_{NBA} \right). \end{aligned} \tag{11}$$

The first term in above equation is the "Domar weighted" aggregate MFP growth (Domar 1961). The next four terms are the reallocation effects of four primary factors across industries.

Given the way we defined aggregate factor input in Equation (8), which is unlike the treatment in Jorgenson, Ho and Stiroh (2002), the reallocation effects are essentially zero. Thus Equation (11) is essentially:

$$(12) \qquad \Delta \ln A = \sum_{i=1}^{34} \frac{\tilde{w}_i}{\overline{v}_{v,i}} \Delta \ln A_i \ .$$

The weights, $\tilde{w}_i / \overline{v}_{v,i}$, are the Domar weights, which sum to more than one (roughly the ratio of total gross output to total value added). As shown later in Table 20, it is around two for both Canada and the United States. This total reflects the fact that, at the aggregate level, output is based on value added, while at the industry level, output is based on gross output which includes intermediate input. As noted by Jorgenson and Stiroh (2000), the weighted aggregate MFP typically grows faster than MFP at the industry level since the efficiency gains are magnified as they work their way through the production process.

Data and Measurement Issues

TO IMPLEMENT THE ABOVE FRAMEWORK we require comparable Canada and U.S. business sector KLEMS (capital, labour, energy materials, and services), data for the 1981-2000 period. These data include volume indexes of gross output, capital services, labour services, intermediate inputs, the number of hours at work and cost in dollars of each of these inputs. The data source for the United States is Jorgenson, Ho, and Stiroh (2002). They have developed such a dataset for 44 industries. The present study collapses the 44 industries into the 34 common industries (Table 1) using Tornqvist aggregation indexes. The Canadian data are obtained from the Canadian Productivity Accounts which produce and maintain a consistent set of detailed industry (122 industries) and aggregated data on inputs and outputs (current prices and chained Fisher indexes) for productivity measurement and related economic performance analysis.[15] The 122 industries are aggregated into the 34 industries in the same fashion. The Canadian and U.S. data used in this study employ concepts and methods which accord with the Organisation for Economic Co-operation and Development

(OECD) productivity manual, thereby making the comparison between the two countries reliable.

Note, however, that like many other studies, the estimates in this study are subject to measurement errors for both output and inputs, especially for those in the services industries. Estimates for industries with consistently negative productivity growth should be interpreted with caution (for possible reasons for consistently negative productivity growth, see Rao, Sharpe, and Tang, 2003).

For this study, gross output and intermediate input values come from a time series of consistent input-output tables. The price indexes for output also are from Statistics Canada and are also used to construct prices of intermediate inputs. The input-output tables are generally recorded in a very similar fashion in Canada and the United States. Thus, output and intermediate inputs are fairly comparable. However, our construction of capital and labour inputs is more complicated and some elaboration is in order here.

Capital Input

Capital stock for each type of asset is constructed by using investment data in constant dollars. Thus, investment price is important for the comparability of capital input in Canada and the United States. This is especially true for IT assets since there is no standard methodology to estimate IT investment prices.

IT assets for both Canada and the United States are computer equipment, communication equipment, and software. The IT has become increasingly important in total machinery and equipment investment.[16] The investment price indexes for those assets diverge significantly across OECD countries due to different methodologies used in estimating the indexes.[17] Thus, it is important here to document the methodology used in Canada and the United States. Fortunately, the methods used by Canada and the United States to develop the IT price indexes are fairly similar. Statistical agencies in Canada and the United States have worked very closely and made extensive use of the hedonic regression technique and the match model technique in estimating the prices of IT.[18] IT price indexes comparisons and a detailed documentation of the methodologies used to construct IT price indexes are given in Appendix B.

It should be noted that the two countries estimate capital stock at the industry level in quite different ways. The United States calculates aggregated flows from commodity data and then spread them using the Tangible Wealth Survey produced by the Bureau of Economic Analysis (BEA)—a method that is indirect and does not allow for very detailed annual changes. For Canada, capital stock data are constructed from investment series by asset classes that are collected from an investment survey of establishments at the industry level. For this project, the data are taken from that contained in the input-output tables and depreciation rates are based on age-price profile using used asset prices that are collected on dispositions of assets by the same industry based survey (Harchaoui et al. 2002). There are 28 non-residential asset types in the Canadian classification, and 52 in the United States. The capital stocks are estimated for all types of assets owned by each industry using the perpetual inventory method and geometric depreciation.

The geometric depreciation rates for 26 non-residential reproducible capital assets in Canada are listed in Table 2.[19] With the exception of software assets, all of non residential capital assets depreciation rates were based on an age-price profile method using 30,000 observations on used asset prices collected by a Statistics Canada survey (Gellatly, Tanguay, and Yan 2003). The U.S. depreciation rates for the same 26 assets are also given in Table 1, which are derived from 52 assets. For automobiles and computers, the U.S. geometric depreciation rates are based on Jorgenson, Ho, and Stiroh (1999). The remaining assets are from the U.S. Bureau of Economic Analysis, derived from a variety of sources (Fraumeni 1997).

The depreciation rates are significantly higher in Canada than in the United States for IT and structures. Our experiments with Canadian aggregate investment data show that this may under- or over-estimate capital stock growth of an asset in Canada relative to the United States, depending on the growth rate of investment in the asset—though it has less of an influence on the growth of capital services that are used here. If the asset is a faster growth investment, then a higher depreciation rate will lead to a higher growth of capital stock. This is the case for IT investment, especially for the second half of the 1990s. On the other hand, if the asset is a slower growth investment, then a higher depreciation rate will lead to a slower growth of capital stock. This is the case for structures. Therefore, the difference in the usage of depreciation rates in deriving IT and non-capital inputs will generally lead to higher IT capital and lower non-IT capital contribution to economic growth. Similarly, it will lead to a higher contribution of IT capital deepening or a lower contribution of non-IT capital deepening to labour productivity growth.

Table 2

Depreciation Rates of Non-residential Reproducible Capital Assets in Canada and the United States

	Reproducible Assets	Canada	United States
	High-Tech		
1	Computers and Office Equipment	0.51	0.22
2	Communication Equipment	0.20	0.11
3	Pre-packaged Software	0.67	0.32
4	Custom Designed Software	0.40	0.32
5	Own Account Software	0.40	0.32
	Low-tech		
6	Office Furniture, Furnishing	0.33	0.11
7	Household and Services Machinery and Equipment	0.14	0.17
8	Electrical Industrial Machinery and Equipment	0.19	0.07
9	Non-electrical Industrial Machinery and Equipment	0.22	0.12
10	Industrial Containers	0.05	0.11
11	Conveyors and Industrial Trucks	0.18	0.19
12	Automobiles and Buses	0.20	0.23
13	Trucks (Excluding Industrial Trucks) and Trailers	0.20	0.19
14	Locomotives, Ships and Boats (Including Major Replacement Parts)	0.12	0.06
15	Aircraft, Aircraft Engines and Other Major Replacement Parts	0.06	0.08
16	Other Equipments	0.20	0.15
	Structures		
17	Non-residential Building Construction	0.07	0.03
18	Road, Highway and Airport Runway Construction	0.10	0.03
19	Gas, Oil Facility Construction	0.08	0.05
20	Electric Power, Dams and Irrigation Construction	0.06	0.02
21	Railway and Telecommunications Construction	0.10	0.02
22	Other Engineering Construction	0.08	0.04
	Tenants Occupied Dwelling		
23	Singles	0.02	0.01
24	Multiples	0.02	0.01
25	Mobiles	0.02	0.05
26	Cottages	0.02	0.02

Sources: Software and assets associated with tenants occupied dwelling for Canada are from conversation with the Investment and Capital Stock Division of Statistics Canada and the rest are from Gellatly, Tanguay and Yan (2003). For the United States, it was based on Jorgenson, Ho and Stiroh (1999).

The difference in depreciation rates may also lead to a different estimate of MFP growth rate due to MFP being calculated as residuals of gross output net all inputs. Given that the value of structures is much larger than that of IT, the overall impact may lead to a higher estimate of MFP growth rate. However, further study is required for reaching a firm conclusion.

Labour Input

In our framework, labour inputs for each industry are hours worked aggregated over the demographic groups using labour compensation as weights. The labour categories used for Canada include seven age groups, four education attainment groups, two sexes and two classes of employment. The classification details are listed in Table 3 for both countries. The labour force categories for the two countries are generally similar except for education.[20] In the Canadian calculations, B.A. degree and above is a single group, whereas in the U.S. data it is divided into B.A. and more than B.A. However, our experiments with U.S. data show that this distinction has a negligible impact on the labour input estimates.

For Canada, the labour data are derived from the Census of Population, supplemented by the annual Survey of Consumer Finance and the monthly Labour Force Surveys. The estimates of hours worked and labour compensation for each industry are benchmarked to official measures of hours worked and compensation by Statistics Canada. A detailed description is given in Gu, Kaci, Maynard, and Sillamaa (2003).

For the United States, the labour data are derived from the Census of Population and the annual Current Population Survey, supplemented by U.S. National Income and Product Account (NIPA) data produced by the U.S. Bureau of Economic Analysis (BEA). The final estimates of hours, based on the hours paid from the BEA, for each industry is scaled to hours worked from the Survey of Hours at Work by the U.S. Bureau of Labor Statistics. Similarly, the individual labour compensation data from the population surveys are scaled so that total labour compensation in each industry matches the NIPA totals. For a detailed discussion, see Jorgenson, Ho, and Stiroh (2002).

Table 3

Labour Force Matrix in Canada and the United States, 1981-2000

Canada			
Characteristics	**Number of Categories**		**Type**
Sex	2		Female, male
Class of Employment	2		Paid employees, self-employed
Age	7		15-17, 18-24, 25-34, 35-44, 45-54, 55-64, 65+ years
Education	4		0-8 years grade school, some or completed high school, some or completed post-secondary, university or above
United States			
Characteristics	**Number of Categories**		**Type**
Sex	2		Female, male
Class of Employment	2		Paid employees, self-employed
Age	7		16-17, 18-24, 25-34, 35-44, 45-54, 55-64, 65+ years
Education	6	1981-1992	0-8 years grade school, 1-3 years high school, 4 years high school, 1-3 years college, 4 years college, 5 years college or more
		1992-2000	0-8 years grade school; grade 9-12, no diploma; high school graduate; some college, no B.A.; bachelor's degree; more than B.A. degree

Growth Accounting Results

WE NOW REPORT THE RESULTS FROM APPLYING THE FRAMEWORK developed in the second section, beginning with the accounts from each of the 34 industries. We first examine the sources of output growth and then the sources of labour productivity growth in individual industries in Canada and the United States. Finally in the section entitled *Aggregate Growth and Sector Contributions*, we report results on the decomposition of the growth in aggregate output and aggregate labour productivity in both countries.

Sources of Economic Growth at the Industry Level

Based on Equation (2), gross output growth of each industry is decomposed into MFP and the contributions associated with the five inputs — IT capital, non-IT capital, university labour, non-university labour and intermediate inputs. The decomposition results for Canada are reported in Tables 4 through 6 for three sub-periods: 1981-88, 1988-95, and 1995-2000.[21] The results for the United States are in Tables 7 through 9. For analytical purposes, we also report averages for the IT-producing, IT-using, and non-IT groups.[22]

IT-producing Industries

By any standard, the output growth in the three IT-producing industries has been extraordinary. In Canada, gross output of the computer equipment industry grew at 16.5 percent per year in the late 1990s after a growth of 23.5 percent in the 1980s. Over the latter half of the 1990s, gross output of the communication and electronic equipment industry grew at 14.5 percent, compared to 5.7 percent growth rate in the communications industry. The U.S. growth rates were even more astounding in the boom period of 1995-2000: computer equipment at 31.5 percent per year, communication and electronic equipment at 23.5 percent and communications at 6.4 percent. On average, gross output in IT-producing industries grew at an annual rate of 8.5 percent in Canada and 10.5 percent in the United States over the past 20 years.

The unprecedented output growth rates were mainly due to the strong growth in MFP and intermediate input. Over the last 20 years, the average MFP growth in the three IT-producing industries in Canada was 2.3 percent while in the United States, it was 4.2 percent. The contribution from the intermediate input was also sizable — 4.1 percentage points in Canada and 4.5 percentage points in the United States. The contributions from other factors such as IT capital and university-labour were relatively small. However, the absolute contributions of IT investment to output growth in these industries are considerably larger than in the IT-using or non-IT industries.

Gross output growth in the U.S. IT-producing industries accelerated in the second half of the 1990s from the first half mainly due to the increase in MFP growth and the increased contribution from intermediate inputs. By contrast, the acceleration in output growth in Canada was relatively small.

IT-using Industries

IT-using industries, on average, grew faster than non-IT industries in both Canada and the United States in the second half of the 1990s. In Canada, the gross output growth of these industries was due to a higher growth in intermediate input and non-university labour, followed by non-IT and IT capital. In the United States, IT investments again played a larger role. Of the 5.0 percent annual output growth, intermediate input contributed 2.3 percent and IT capital 1.0 percent. In both countries, MFP growth did not play a significant role in these industries.

The acceleration in output growth during the second half of the 1990s was much greater in Canada than in the United States. However, the sources of increase in output growth were different in the two countries. In Canada, the biggest change was non-university labour, the growth rate of which changed from 0.1 to 1.0 percent per year, while in the United States, IT capital growth rose from 0.4 to 1.0 percent.

Table 4

Sources of Gross Output Growth in Canadian Industries, 1981-88

Industry	Gross Output	Contributions					
		MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
1 Agriculture	0.87	1.35	0.00	–0.53	0.03	0.06	-0.04
2 Non-energy Mining	1.31	1.60	0.01	0.21	0.05	–0.49	-0.08
3 Coal Mining	8.96	7.25	0.00	0.72	–0.03	–0.10	1.12
4 Crude Petroleum	4.00	0.94	0.01	2.87	0.14	0.24	-0.20
5 Construction	1.57	–0.01	0.03	0.08	0.05	0.55	0.87
6 Wood and Furniture	4.91	1.41	0.02	0.03	0.08	0.48	2.89
7 Non-metallic	2.26	1.11	0.03	–0.36	0.07	0.10	1.31
8 Primary Metal	2.16	1.04	0.07	–0.04	0.00	–0.32	1.41
9 Fabricated Metal	1.46	0.56	0.06	–0.02	0.03	0.04	0.78
10 Machinery	0.72	–0.07	0.06	–0.25	0.12	0.45	0.41
11 Computers	23.49	9.84	0.32	1.21	0.37	0.23	11.52
12 Electrical Equipment	1.08	0.44	0.14	0.06	0.12	–0.55	0.87
13 Electronic Equipment	8.54	0.85	0.37	0.85	0.60	0.99	4.88
14 Motor Vehicles	9.79	0.91	0.06	0.63	0.06	0.63	7.50
15 Other Trans. Equipment	0.20	–0.81	0.06	0.00	0.31	–0.24	0.87
16 Misc. Manufacturing	1.72	0.03	0.12	0.22	0.10	0.38	0.86
17 Food and Tobacco	1.04	–0.21	0.03	0.01	0.04	–0.01	1.18
18 Textiles	1.29	0.09	0.03	0.08	0.10	–0.02	1.01
19 Paper and Allied	2.58	–0.13	0.04	0.55	0.03	–0.01	2.12
20 Printing	3.26	–0.48	0.08	0.33	0.11	1.17	2.04
21 Chemicals	2.90	1.02	0.06	–0.23	0.07	0.09	1.89

Table 4 (cont'd)

Sources of Gross Output Growth in Canadian Industries, 1981-88

		Contributions					
Industry	**Gross Output**	**MFP**	**IT Capital**	**Non-IT Capital**	**University Labour**	**Non-university Labour**	**Intermediate Input**
22 Petroleum Refining	–2.03	–1.44	0.02	–0.01	–0.04	–0.14	-0.41
23 Rubber and Plastics	5.17	0.69	0.10	0.52	0.05	0.85	2.95
24 Transportation	3.63	1.61	0.09	0.15	0.09	0.33	1.36
25 Communications	5.39	2.42	0.84	0.45	0.26	0.20	1.23
26 Electric Utilities	3.57	1.14	0.61	0.52	0.11	0.09	1.10
27 Gas Utilities	1.49	–1.72	0.32	1.95	0.23	0.48	0.24
28 Wholesale Trade	6.00	2.80	0.13	0.43	0.35	0.78	1.52
29 Retail Trade	3.33	0.42	0.12	0.33	0.26	1.27	0.93
30 FIRE	3.38	–1.13	0.41	1.52	0.29	0.41	1.88
31 Business Services	6.39	–0.91	0.65	0.79	1.90	1.83	2.14
32 Health Services	4.73	–1.34	0.15	0.29	1.77	2.12	1.74
33 Education, Private	1.84	–2.99	0.49	0.15	1.51	1.70	0.97
34 Other Services	3.01	–1.18	0.56	0.60	0.29	1.07	1.66
Industry Group							
IT-producing Industries	8.05	2.83	0.67	0.62	0.35	0.39	3.19
IT-using Industries	3.69	0.01	0.27	0.74	0.44	0.77	1.46
Non-IT Industries	2.73	0.34	0.11	0.33	0.12	0.34	1.49

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
The gross output column shows the growth rates, the five columns of input contributions indicate the growth rates multiplied by the share weights, and the multifactor productivity (MFP) column provides growth rates.

Table 5

Sources of Gross Output Growth in Canadian Industries, 1988-95

			Contributions					
Industry		Gross Output	MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
1	Agriculture	3.15	1.99	0.03	–0.40	0.11	–0.16	1.58
2	Non-energy Mining	0.03	0.24	0.02	–0.40	0.14	0.00	0.03
3	Coal Mining	–0.31	1.26	0.02	–1.42	0.00	0.18	-0.35
4	Crude Petroleum	3.53	1.55	0.01	0.95	0.02	–0.08	1.08
5	Construction	–1.82	–0.66	0.02	0.08	0.06	–0.29	-1.02
6	Wood and Furniture	0.76	–0.40	0.02	0.16	0.08	–0.20	1.10
7	Non-metallic	–3.01	–0.46	0.05	–0.25	0.07	–1.01	-1.41
8	Primary Metal	1.45	1.45	0.03	–0.27	0.00	–0.56	0.80
9	Fabricated Metal	–1.13	0.14	0.01	–0.17	0.05	–0.37	-0.78
10	Machinery	3.27	1.17	0.08	0.36	0.12	–0.35	1.87
11	Computers	19.81	3.43	0.11	0.12	0.04	–0.19	16.31
12	Electrical Equipment	–3.40	0.22	0.11	–0.31	–0.01	–1.34	-2.07
13	Electronic Equipment	9.30	2.46	0.13	0.19	0.50	–0.58	6.60
14	Motor Vehicles	4.84	0.65	0.01	0.19	0.08	0.03	3.88
15	Other Trans. Equipment	2.89	0.96	0.02	0.19	0.13	–0.65	2.24
16	Misc. Manufacturing	0.25	0.18	0.12	0.12	0.21	–0.49	0.10
17	Food and Tobacco	0.60	0.28	0.08	–0.14	0.10	–0.18	0.46
18	Textiles	–1.93	0.86	0.03	–0.21	0.07	–1.33	-1.36
19	Paper and Allied	1.29	1.55	0.02	–0.56	0.05	–0.38	0.60
20	Printing	–2.29	–1.92	0.21	0.18	0.19	–0.47	-0.48

Table 5 (cont'd)

Sources of Gross Output Growth in Canadian Industries, 1988-95

Industry	Gross Output	Contributions					
		MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
21 Chemicals	1.44	0.77	0.11	0.18	0.16	–0.22	0.44
22 Petroleum Refining	1.07	0.52	0.04	–0.09	0.06	–0.13	0.66
23 Rubber and Plastics	3.20	0.92	0.08	0.09	0.15	0.00	1.96
24 Transportation	2.18	0.14	0.10	0.33	0.21	0.44	0.97
25 Communications	4.70	0.60	1.63	0.95	0.40	–0.09	1.21
26 Electric Utilities	1.81	–0.92	0.21	0.96	0.22	0.23	1.11
27 Gas Utilities	3.11	–0.84	0.27	1.96	0.39	0.62	0.70
28 Wholesale Trade	3.20	0.53	0.21	0.33	0.54	0.49	1.10
29 Retail Trade	1.76	–0.06	0.17	0.32	0.33	0.22	0.79
30 FIRE	3.37	0.72	0.34	0.61	0.49	0.05	1.15
31 Business Services	4.15	–1.37	0.53	0.92	1.69	0.50	1.87
32 Health Services	1.96	–0.21	0.10	0.19	0.43	0.93	0.52
33 Education, Private	1.68	–2.50	0.21	0.08	1.93	0.46	1.50
34 Other Services	1.63	–0.58	0.21	0.23	0.31	0.40	1.06
Industry Group							
IT-producing Industries	7.86	1.39	1.02	0.65	0.39	–0.24	4.65
IT-using Industries	2.63	0.15	0.27	0.47	0.57	0.10	1.07
Non-IT Industries	1.22	0.20	0.07	0.11	0.14	–0.05	0.76

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
The gross output column shows the growth rates, the five columns of input contributions indicate the growth rates multiplied by the share weights, and the multifactor productivity (MFP) column provides growth rates.

Table 6

Sources of Gross Output Growth in Canadian Industries, 1995-2000

			Contributions					
Industry		**Gross Output**	**MFP**	**IT Capital**	**Non-IT Capital**	**University Labour**	**Non-university Labour**	**Intermediate Input**
1	Agriculture	3.53	2.12	0.07	0.38	0.04	–0.55	1.48
2	Non-energy Mining	0.76	–0.86	0.05	0.82	0.17	0.84	-0.26
3	Coal Mining	–1.65	2.55	0.06	–1.22	–0.08	–1.16	-1.81
4	Crude Petroleum	4.39	–2.57	0.04	3.79	0.07	0.09	2.97
5	Construction	3.62	0.19	0.04	0.16	0.14	1.11	1.97
6	Wood and Furniture	5.35	0.83	0.03	0.40	0.09	0.69	3.30
7	Non-metallic	5.11	1.85	0.07	0.05	0.15	0.63	2.36
8	Primary Metal	4.74	0.96	0.04	0.29	0.05	0.22	3.19
9	Fabricated Metal	6.12	0.49	0.07	0.49	0.18	1.31	3.57
10	Machinery	1.73	–1.20	0.15	0.56	0.19	1.17	0.84
11	Computers	16.52	5.91	0.12	0.12	0.14	0.20	10.04
12	Electrical Equipment	4.38	0.01	0.30	0.91	0.24	0.68	2.25
13	Electronic Equipment	14.49	3.27	0.25	1.46	0.35	0.45	8.71
14	Motor Vehicles	7.96	1.23	0.04	0.29	0.07	0.44	5.90
15	Other Trans. Equipment	7.13	–1.09	0.06	2.03	0.20	0.64	5.30
16	Misc. Manufacturing	5.55	0.48	0.25	0.51	0.22	0.61	3.49
17	Food and Tobacco	2.87	–0.50	0.14	0.33	0.09	0.32	2.48
18	Textiles	1.30	–0.72	0.09	0.12	0.16	0.50	1.16
19	Paper and Allied	1.83	0.28	0.07	0.57	0.04	0.19	0.68
20	Printing	3.89	–1.66	0.42	0.34	0.34	0.94	3.52

Table 6 (cont'd)

Sources of Gross Output Growth in Canadian Industries, 1995-2000

Industry	Gross Output	Contributions					
		MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
21 Chemicals	2.24	0.18	0.13	0.45	0.23	0.25	0.99
22 Petroleum Refining	2.75	–0.05	0.01	–0.03	0.12	0.23	2.47
23 Rubber and Plastics	6.22	0.29	0.10	0.58	0.22	1.03	4.00
24 Transportation	3.78	0.39	0.24	0.65	0.13	0.81	1.55
25 Communications	5.69	1.71	2.04	0.97	0.01	–0.05	1.01
26 Electric Utilities	0.67	0.80	0.45	–1.31	0.03	0.06	0.64
27 Gas Utilities	0.99	–0.95	0.69	1.61	–0.10	–0.34	0.07
28 Wholesale Trade	6.71	0.85	0.38	0.57	0.56	1.88	2.46
29 Retail Trade	5.50	1.86	0.39	0.39	0.20	0.46	2.20
30 FIRE	4.99	0.96	0.59	0.46	0.25	0.32	2.41
31 Business Services	11.37	0.15	0.65	1.05	2.68	2.20	4.64
32 Health Services	4.55	–3.78	0.09	0.15	5.00	1.23	1.85
33 Education, Private	22.35	4.33	0.12	0.03	8.84	4.07	4.96
34 Other Services	5.38	0.97	0.32	0.19	0.25	0.77	2.88
Industry Group							
IT-producing Industries	10.04	2.91	1.19	1.04	0.14	0.14	4.61
IT-using Industries	6.28	0.67	0.47	0.63	0.68	0.99	2.84
Non-IT Industries	4.31	0.30	0.12	0.42	0.31	0.57	2.59

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
The gross output column shows the growth rates, the five columns of input contributions indicate the growth rates multiplied by the share weights, and the multifactor productivity (MFP) column provides growth rates.

Table 7

Sources of Gross Output Growth in U.S. Industries, 1981-88

Industry	Gross Output	Contributions					
		MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
1 Agriculture	0.77	1.63	0.01	–0.26	0.14	–0.17	-0.58
2 Non-energy Mining	1.56	1.31	0.03	–0.56	–0.14	–1.06	1.97
3 Coal Mining	2.09	3.29	0.01	–0.36	–0.06	–1.85	1.07
4 Crude Petroleum	–2.45	0.28	0.07	1.25	–0.24	–0.57	-3.25
5 Construction	3.31	–0.14	0.00	–0.11	0.29	1.24	2.04
6 Wood and Furniture	4.15	1.35	0.03	0.06	0.18	0.68	1.85
7 Non-metallic	2.11	1.24	0.01	–0.12	0.15	0.00	0.83
8 Primary Metal	–1.89	0.83	0.04	–0.32	–0.02	–0.62	-1.80
9 Fabricated Metal	1.37	0.66	0.08	0.06	0.02	–0.25	0.80
10 Machinery	–1.75	–0.77	0.21	0.14	0.12	–1.05	-0.40
11 Computers	22.44	11.53	0.11	0.01	0.82	–0.18	10.14
12 Electrical Equipment	2.44	1.21	0.17	–0.06	0.39	–0.71	1.44
13 Electronic Equipment	10.50	4.72	0.55	1.12	0.57	–0.04	3.58
14 Motor Vehicles	6.59	0.79	0.03	0.02	0.05	0.13	5.56
15 Other Trans. Equipment	3.29	0.05	0.31	0.22	0.64	0.06	2.01
16 Misc. Manufacturing	3.66	1.03	0.26	0.31	0.57	–0.10	1.60
17 Food and Tobacco	1.82	1.04	0.07	0.14	0.05	–0.16	0.67
18 Textiles	1.38	0.71	0.04	0.04	0.13	–0.57	1.03
19 Paper and Allied	2.73	0.20	0.06	0.30	0.17	0.13	1.86
20 Printing	4.16	–0.43	0.36	0.46	0.71	0.53	2.52

Table 7 (cont'd)

Sources of Gross Output Growth in U.S. Industries, 1981-88

		Contributions					
Industry	**Gross Output**	**MFP**	**IT Capital**	**Non-IT Capital**	**University Labour**	**Non-university Labour**	**Intermediate Input**
21 Chemicals	1.18	0.78	0.13	0.11	0.28	–0.25	0.13
22 Petroleum Refining	2.09	3.76	0.01	0.03	0.02	–0.10	–1.63
23 Rubber and Plastics	5.79	1.69	0.06	0.17	0.30	0.62	2.96
24 Transportation	3.39	0.82	0.07	–0.10	0.62	0.30	1.69
25 Communications	1.50	–0.35	0.74	0.75	0.23	–0.48	0.61
26 Electric Utilities	2.24	–0.60	0.43	1.17	0.18	0.00	1.05
27 Gas Utilities	–4.74	–3.76	0.13	0.10	0.00	–0.11	–1.10
28 Wholesale Trade	4.94	1.89	0.75	0.79	0.36	0.42	0.73
29 Retail Trade	3.23	–0.14	0.23	0.36	0.44	0.84	1.50
30 FIRE	4.45	–0.75	0.57	1.72	0.62	0.24	2.05
31 Business Services	6.17	–1.43	2.05	0.26	2.18	1.79	1.31
32 Health Services	4.07	–0.48	0.43	0.69	1.39	0.87	1.17
33 Education, Private	3.34	–1.03	0.04	0.10	2.07	0.06	2.11
34 Other Services	3.81	0.19	0.06	0.39	0.34	1.04	1.78
Industry Group							
IT Producing Industries	7.83	3.26	0.57	0.68	0.43	–0.32	3.20
IT-Using Industries	3.78	–0.08	0.59	0.79	0.64	0.39	1.45
Non-IT Industries	2.26	0.31	0.12	0.25	0.37	0.28	0.93

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
The gross output column shows the growth rates, the five columns of input contributions indicate the growth rates multiplied by the share weights, and the multifactor productivity (MFP) column provides growth rates.

Table 8

Sources of Gross Output Growth in U.S. Industries, 1988-95

			Contributions					
Industry		Gross Output	MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
1	Agriculture	2.73	1.67	0.03	0.10	0.36	–0.08	0.66
2	Non-energy Mining	2.33	1.09	0.18	0.18	0.28	0.01	0.60
3	Coal Mining	1.14	3.40	0.15	–0.20	0.07	–1.13	-1.15
4	Crude Petroleum	–1.27	0.20	0.06	–0.75	0.14	–0.28	-0.66
5	Construction	–0.65	–1.33	0.06	0.05	0.12	0.38	0.07
6	Wood and Furniture	0.62	–1.11	0.06	0.01	0.00	0.18	1.49
7	Non-metallic	0.46	0.38	0.04	–0.10	–0.02	0.02	0.14
8	Primary Metal	1.00	0.64	0.04	–0.04	–0.04	–0.11	0.52
9	Fabricated Metal	1.60	0.46	0.11	0.03	–0.04	0.24	0.81
10	Machinery	2.97	–0.02	0.30	0.29	0.12	0.35	1.94
11	Computers	16.26	10.22	0.04	–0.24	–0.52	–0.43	7.18
12	Electrical Equipment	2.23	1.03	0.03	–0.47	0.07	–0.25	1.82
13	Electronic Equipment	14.54	6.82	0.51	1.32	0.00	–0.25	6.14
14	Motor Vehicles	3.27	–0.18	0.04	0.11	0.08	0.31	2.92
15	Other Trans. Equipment	–3.08	0.70	0.02	–0.05	–0.48	–1.69	–1.57
16	Misc. Manufacturing	1.24	–0.48	0.34	0.14	0.27	–0.55	1.52
17	Food and Tobacco	1.57	0.10	0.07	0.18	0.06	0.08	1.08
18	Textiles	1.13	0.57	0.08	0.04	0.07	–0.33	0.69
19	Paper and Allied	1.23	–0.65	0.08	0.32	0.14	0.08	1.26
20	Printing	–0.16	–1.21	0.40	0.09	0.43	–0.01	0.14

Table 8 (cont'd)

Sources of Gross Output Growth in U.S. Industries, 1988-95

Industry		Gross Output	Contributions					
			MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
21	Chemicals	1.47	–0.14	0.18	0.45	0.22	–0.08	0.83
22	Petroleum Refining	0.28	–0.43	0.02	0.14	0.02	–0.05	0.58
23	Rubber and Plastics	4.13	0.88	0.10	0.35	0.24	0.62	1.94
24	Transportation	3.40	0.36	0.16	–0.01	0.28	1.10	1.51
25	Communications	3.76	0.13	0.99	0.70	0.35	–0.01	1.60
26	Electric Utilities	1.31	0.85	0.15	0.18	0.13	–0.23	0.22
27	Gas Utilities	–2.59	–0.90	0.33	0.08	0.07	–0.06	-2.11
28	Wholesale Trade	3.72	0.91	0.76	0.27	0.36	0.25	1.17
29	Retail Trade	1.86	–0.18	0.13	0.40	0.11	0.57	0.83
30	FIRE	2.92	0.37	0.59	0.72	0.36	–0.06	0.94
31	Business Services	5.39	0.54	0.57	0.46	0.54	1.34	1.94
32	Health Services	2.92	–1.49	0.26	0.39	1.19	1.04	1.53
33	Education, Private	1.85	–1.09	0.04	0.02	1.41	0.43	1.04
34	Other Services	3.04	–0.53	0.15	0.64	0.34	0.62	1.82
Industry Group								
IT-producing Industries		9.04	3.84	0.69	0.70	0.09	–0.14	3.86
IT-using Industries		2.63	0.25	0.44	0.42	0.27	0.21	1.04
Non-IT Industries		1.72	–0.35	0.13	0.19	0.37	0.38	1.01

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
The gross output column shows the growth rates, the five columns of input contributions indicate the growth rates multiplied by the share weights, and the multifactor productivity (MFP) column provides growth rates.

Table 9

Sources of Gross Output Growth in U.S. Industries, 1995-2000

Industry	Gross Output	Contributions					
		MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
1 Agriculture	3.33	1.94	0.05	0.37	–0.34	0.25	1.07
2 Non-energy Mining	1.80	0.46	0.18	0.55	–0.30	–0.13	1.04
3 Coal Mining	0.80	3.57	0.18	0.08	–0.46	–1.47	–1.10
4 Crude Petroleum	1.10	0.98	0.18	0.39	–0.34	–0.04	–0.06
5 Construction	4.48	–0.95	0.12	0.41	0.18	1.49	3.23
6 Wood and Furniture	3.25	0.86	0.10	0.20	0.19	0.41	1.49
7 Non-metallic	5.60	0.87	0.24	0.64	0.25	0.43	3.17
8 Primary Metal	3.04	2.50	0.08	0.13	0.07	0.00	0.27
9 Fabricated Metal	5.58	1.63	0.20	0.29	0.19	0.34	2.94
10 Machinery	3.88	0.24	0.57	0.28	0.03	0.18	2.58
11 Computers	31.50	16.76	0.29	0.37	–0.09	0.07	14.10
12 Electrical Equipment	3.56	0.94	0.09	–0.35	0.03	–0.12	2.98
13 Electronic Equipment	23.47	11.31	0.87	1.81	0.14	0.38	8.96
14 Motor Vehicles	6.07	0.65	0.06	0.22	0.10	0.08	4.97
15 Other Trans. Equipment	5.99	0.94	0.31	0.10	0.73	–0.20	4.10
16 Misc. Manufacturing	4.18	–0.24	0.53	0.21	0.74	–0.27	3.22
17 Food and Tobacco	1.52	0.01	0.12	0.33	0.03	0.03	1.00
18 Textiles	–1.07	2.13	0.11	–0.03	–0.25	–1.23	–1.80
19 Paper and Allied	0.79	1.83	0.11	0.19	–0.04	–0.15	–1.14
20 Printing	1.97	0.56	0.80	0.13	0.09	–0.07	0.46

Table 9 (cont'd)

Sources of Gross Output Growth in U.S. Industries, 1995-2000

Industry	Gross Output	Contributions					
		MFP	IT Capital	Non-IT Capital	University Labour	Non-university Labour	Intermediate Input
21 Chemicals	2.20	0.50	0.26	0.51	0.07	0.04	0.82
22 Petroleum Refining	1.50	–3.71	0.01	–0.10	–0.07	–0.08	5.46
23 Rubber and Plastics	3.45	1.51	0.20	0.53	0.11	0.18	0.93
24 Transportation	2.81	–0.22	0.40	0.45	0.18	0.67	1.33
25 Communications	6.41	–1.20	1.84	0.90	0.52	0.59	3.76
26 Electric Utilities	2.87	2.33	0.22	0.21	0.00	–0.40	0.50
27 Gas Utilities	–0.65	0.33	0.34	0.34	–0.04	–0.26	-1.36
28 Wholesale Trade	4.16	0.08	1.41	0.55	0.24	0.43	1.45
29 Retail Trade	4.17	1.31	0.30	0.44	0.33	0.31	1.47
30 FIRE	5.26	0.01	1.18	1.00	0.44	0.17	2.45
31 Business Services	8.15	–1.38	1.76	0.83	1.50	1.87	3.59
32 Health Services	3.67	–1.07	0.57	0.53	1.37	0.57	1.71
33 Education, Private	2.87	–1.55	0.09	0.07	2.24	0.41	1.62
34 Other Services	4.42	0.51	0.23	0.48	0.31	0.49	2.40
Industry Group							
IT-producing Industries	16.22	5.88	1.27	1.09	0.29	0.44	7.25
IT-using Industries	5.02	0.12	1.00	0.64	0.52	0.43	2.31
Non-IT Industries	3.32	0.11	0.25	0.38	0.38	0.39	1.79

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
The gross output column shows the growth rates, the five columns of input contributions indicate the growth rates multiplied by the share weights, and the multifactor productivity (MFP) column provides growth rates.

Sources of Labour Productivity Growth at the Industry Level

Equation (3) shows the relationship between labour productivity growth and MFP growth, capital deepening, labour quality change and intermediate input deepening. The results on sources of labour productivity growth in Canadian industries reported in Tables 10 through 12 for the three periods: 1981-88, 1988-95, and 1995-2000. Results for the United States are reported in Tables 13 through 15.

IT-producing Industries

The story that is familiar to many is the unprecedented rate of labour productivity growth in the computer equipment, and communications and electronic equipment industries in all OECD countries. What may be less well known is that labour productivity growth in our third IT-producing industry, communications, is a laggard in the United States but grew rapidly in Canada. Over the past 20 years, the average growth in labour productivity in these three industries was 7.8 percent in Canada and 9.8 percent in the United States. In the second half of the 1990s, labour productivity in Canadian IT-producing industries increased at an annual rate of 9.0 percent, compared to 12.8 percent in the United States.

These unprecedented growth rates were mainly due to MFP improvements and intermediate input deepening. Over the period 1981-2000, the average MFP growth in the three IT-producing industries in Canada was 2.3 percent per year while in the United States it was 4.2 percent. The contribution from intermediate input deepening was also sizable, 3.8 percentage points in Canada and 4.1 percentage points in the United States. The contributions from other factors such as IT capital and university-labour were small. However, if we look across the three major groups, IT-producing industries in both countries were the largest beneficiaries of capital deepening, especially IT capital deepening.

In the 1980s, the IT-producing industries in Canada were enjoying productivity growth rates similar to their U.S. counterparts, but Canada lagged the United States in labour productivity growth in the 1990s, especially in the second half. The labour productivity growth gap was entirely due to the stronger MFP performance and intermediate input deepening in the United States.

Table 10

Sources of Labour Productivity Growth in Canadian Industries, 1981-88

			Contributions					
Industry	LP	MFP	IT Capital Deepening	Non-IT Capital Deepening	University Labour Quality Improvement	Non-university Labour Quality Improvement	Intermediate Input Intensity
1 Agriculture	1.01	1.35	0.00	–0.51	0.03	0.09	0.03
2 Non-energy Mining	3.52	1.60	0.02	0.80	0.09	0.11	0.90
3 Coal Mining	9.46	7.25	0.00	0.81	–0.02	0.06	1.36
4 Crude Petroleum	–1.26	0.94	0.00	–1.30	0.05	0.03	–0.98
5 Construction	–0.25	–0.01	0.03	–0.04	0.02	0.02	–0.26
6 Wood and Furniture	3.08	1.41	0.02	–0.19	0.05	0.03	1.76
7 Non-metallic	1.96	1.11	0.03	–0.56	0.06	0.09	1.23
8 Primary Metal	4.00	1.04	0.07	0.05	0.02	0.10	2.72
9 Fabricated Metal	1.22	0.56	0.06	–0.14	0.02	0.06	0.65
10 Machinery	–0.92	–0.07	0.06	–0.57	0.07	0.09	–0.49
11 Computers	22.02	9.84	0.30	1.02	0.27	–0.02	10.59
12 Electrical Equipment	3.28	0.44	0.15	0.30	0.16	0.05	2.18
13 Electronic Equipment	4.06	0.85	0.31	0.20	0.26	–0.18	2.62
14 Motor Vehicles	4.91	0.91	0.05	0.21	0.02	–0.04	3.76
15 Other Trans. Equipment	0.33	–0.81	0.06	0.08	0.27	–0.04	0.77
16 Misc. Manufacturing	0.19	0.03	0.11	0.06	0.06	0.03	–0.10
17 Food and Tobacco	1.05	–0.21	0.03	–0.02	0.04	–0.01	1.22
18 Textiles	1.58	0.09	0.03	0.09	0.10	0.08	1.19
19 Paper and Allied	3.04	–0.13	0.04	0.58	0.03	0.10	2.42
20 Printing	–0.02	–0.48	0.06	–0.22	–0.01	0.15	0.47

Table 10 (cont'd)

Sources of Labour Productivity Growth in Canadian Industries, 1981-88

			Contributions					
Industry	**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
21 Chemicals	1.99	1.02	0.05	–0.45	0.03	–0.02	1.35
22 Petroleum Refining	4.03	–1.44	0.03	0.09	0.00	0.03	5.33
23 Rubber and Plastics	1.71	0.69	0.09	0.11	–0.01	0.03	0.81
24 Transportation	2.55	1.61	0.08	–0.06	0.07	–0.04	0.88
25 Communications	4.86	2.42	0.72	0.33	0.23	0.08	1.08
26 Electric Utilities	3.02	1.14	0.61	0.10	0.10	0.03	1.04
27 Gas Utilities	–1.07	–1.72	0.29	0.41	0.16	–0.04	–0.17
28 Wholesale Trade	4.27	2.80	0.12	0.08	0.27	0.02	0.98
29 Retail Trade	0.94	0.42	0.11	–0.01	0.18	0.05	0.19
30 FIRE	1.12	–1.13	0.37	0.80	0.18	–0.09	1.00
31 Business Services	1.16	–0.91	0.54	0.20	0.60	0.10	0.64
32 Health Services	–2.28	–1.34	0.10	–0.90	–0.87	0.53	0.20
33 Education, Private	–6.47	–2.99	0.38	–0.03	0.16	–0.31	–3.69
34 Other Services	0.18	–1.18	0.51	0.22	0.19	–0.07	0.51
Industry Group							
IT-producing Industries	6.36	2.83	0.44	0.27	0.26	–0.03	2.59
IT-using Industries	1.16	0.01	0.24	0.22	0.28	–0.08	0.49
Non-IT Industries	1.17	0.34	0.10	0.03	0.08	–0.02	0.63

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
"LP" and "MFP" are the growth rates of labour productivity and multifactor productivity, respectively.

Table 11

Sources of Labour Productivity Growth in Canadian Industries, 1988-95

			Contributions					
Industry		LP	MFP	IT Capital Deepening	Non-IT Capital Deepening	University Labour Quality Improvement	Non-university Labour Quality Improvement	Intermediate Input Intensity
1	Agriculture	4.22	1.99	0.03	–0.20	0.14	0.06	2.19
2	Non-energy Mining	0.07	0.24	0.02	–0.34	0.14	–0.01	0.01
3	Coal Mining	–0.39	1.26	0.02	–1.53	0.00	0.16	-0.30
4	Crude Petroleum	5.37	1.55	0.01	2.05	0.10	0.05	1.60
5	Construction	–0.56	–0.66	0.02	0.16	0.10	0.13	-0.31
6	Wood and Furniture	1.64	–0.40	0.02	0.16	0.10	0.12	1.64
7	Non-metallic	0.58	–0.46	0.07	0.27	0.16	–0.06	0.61
8	Primary Metal	4.88	1.45	0.05	0.03	0.07	0.07	3.22
9	Fabricated Metal	0.42	0.14	0.01	–0.05	0.10	0.11	0.11
10	Machinery	4.15	1.17	0.09	0.36	0.15	0.01	2.36
11	Computers	21.70	3.43	0.13	0.29	0.16	0.04	17.64
12	Electrical Equipment	2.76	0.22	0.17	0.43	0.25	0.04	1.64
13	Electronic Equipment	10.70	2.46	0.15	0.37	0.60	–0.25	7.38
14	Motor Vehicles	4.42	0.65	0.01	0.14	0.07	0.02	3.53
15	Other Trans. Equipment	4.89	0.96	0.03	0.39	0.24	–0.04	3.30
16	Misc. Manufacturing	1.63	0.18	0.13	0.24	0.27	–0.09	0.90
17	Food and Tobacco	1.98	0.28	0.08	0.07	0.12	0.02	1.40
18	Textiles	3.16	0.86	0.05	0.35	0.19	0.03	1.68
19	Paper and Allied	3.44	1.55	0.03	–0.26	0.10	0.07	1.96
20	Printing	–1.08	–1.92	0.23	0.37	0.27	–0.08	0.05

Table 11 (cont'd)

Sources of Labour Productivity Growth in Canadian Industries, 1988-95

			Contributions					
Industry	**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
21 Chemicals	2.67	0.77	0.12	0.43	0.23	–0.07	1.20
22 Petroleum Refining	3.84	0.52	0.05	–0.04	0.10	–0.02	3.23
23 Rubber and Plastics	3.04	0.92	0.07	0.03	0.14	0.00	1.87
24 Transportation	0.74	0.14	0.08	0.11	0.16	–0.05	0.30
25 Communications	4.44	0.60	1.56	0.90	0.39	–0.15	1.14
26 Electric Utilities	0.41	–0.92	0.18	0.08	0.17	0.03	0.87
27 Gas Utilities	–0.45	–0.84	0.22	–0.24	0.22	0.00	0.19
28 Wholesale Trade	1.86	0.53	0.19	0.06	0.45	–0.04	0.66
29 Retail Trade	1.30	–0.06	0.16	0.27	0.30	0.00	0.62
30 FIRE	2.65	0.72	0.32	0.39	0.44	–0.10	0.87
31 Business Services	1.35	–1.37	0.46	0.65	0.89	–0.28	1.00
32 Health Services	–1.84	–0.21	0.07	–0.37	–1.04	0.08	-0.38
33 Education, Private	–3.15	–2.50	0.14	–0.02	0.64	–0.42	-0.99
34 Other services	0.49	–0.58	0.18	0.09	0.25	–0.02	0.57
Industry Group							
IT- producing Industries	8.26	1.39	1.07	0.73	0.41	–0.13	4.80
IT-using Industries	1.83	0.15	0.26	0.31	0.50	–0.13	0.75
Non-IT Industries	1.31	0.20	0.07	0.12	0.14	–0.02	0.80

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
"LP" and "MFP" are growth rates of labour productivity and multifactor productivity, respectively.

Table 12

Sources of Labour Productivity Growth in Canadian Industries, 1995-2000

				Contributions				
	Industry	**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
1	Agriculture	7.06	2.12	0.08	0.98	0.12	0.07	3.70
2	Non-energy Mining	–2.37	–0.86	0.04	–0.04	0.06	0.05	–1.62
3	Coal Mining	3.04	2.55	0.08	0.29	0.02	0.03	0.05
4	Crude Petroleum	2.72	–2.57	0.04	2.81	0.02	0.01	2.40
5	Construction	0.33	0.19	0.03	–0.08	0.05	0.06	0.07
6	Wood and Furniture	1.98	0.83	0.02	–0.14	0.03	–0.04	1.29
7	Non-metallic	2.95	1.85	0.05	–0.32	0.08	0.16	1.13
8	Primary Metal	3.33	0.96	0.03	0.10	0.02	0.01	2.21
9	Fabricated Metal	1.40	0.49	0.06	–0.17	0.04	0.13	0.85
10	Machinery	–3.18	–1.20	0.12	–0.28	0.01	–0.03	–1.79
11	Computers	14.79	5.91	0.09	0.00	0.01	0.01	8.77
12	Electrical Equipment	1.24	0.01	0.25	0.49	0.08	0.10	0.31
13	Electronic Equipment	10.56	3.27	0.20	0.90	0.04	0.04	6.10
14	Motor Vehicles	3.22	1.23	0.03	–0.07	0.01	–0.04	2.05
15	Other Trans. Equipment	3.60	–1.09	0.04	1.35	0.04	–0.02	3.28
16	Misc. Manufacturing	1.98	0.48	0.21	–0.13	0.02	–0.15	1.55
17	Food and Tobacco	0.80	–0.50	0.12	0.01	0.05	0.07	1.04
18	Textiles	–0.47	–0.72	0.08	–0.19	0.10	0.10	0.17
19	Paper and Allied	0.96	0.28	0.07	0.43	0.02	0.04	0.12
20	Printing	0.34	–1.66	0.34	–0.31	0.10	0.01	1.86

Table 12 (cont'd)

Sources of Labour Productivity Growth in Canadian Industries, 1995-2000

		Contributions					
Industry	**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
21 Chemicals	–1.30	0.18	0.10	–0.40	0.05	–0.06	–1.17
22 Petroleum Refining	–3.51	–0.05	0.00	–0.11	0.01	0.01	–3.37
23 Rubber and Plastics	1.43	0.29	0.07	–0.19	0.06	0.03	1.17
24 Transportation	1.33	0.39	0.21	0.24	0.05	0.01	0.43
25 Communications	6.18	1.71	2.11	1.07	0.05	0.08	1.15
26 Electric Utilities	0.17	0.80	0.43	–1.62	0.01	0.02	0.53
27 Gas Utilities	3.45	–0.95	0.73	3.14	0.02	0.04	0.48
28 Wholesale Trade	1.59	0.85	0.29	–0.25	0.11	0.03	0.55
29 Retail Trade	4.28	1.86	0.37	0.22	0.12	–0.07	1.77
30 FIRE	3.33	0.96	0.54	–0.04	0.10	0.03	1.74
31 Business Services	2.61	0.15	0.46	0.42	0.04	0.02	1.52
32 Health Services	–2.11	–3.78	0.05	–0.45	2.06	–0.29	0.30
33 Education, Private	4.81	4.33	–0.02	–0.32	2.31	–0.08	–1.41
34 Other Services	3.27	0.97	0.27	–0.08	0.13	0.04	1.94
Industry Group							
IT-producing Industries	9.02	2.91	1.07	0.86	0.07	0.02	4.08
IT-using Industries	2.33	0.67	0.39	–0.13	0.23	–0.08	1.24
Non-IT Industries	1.86	0.30	0.11	–0.01	0.20	0.06	1.20

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
"LP" and "MFP" are growth rates of labour productivity and multifactor productivity, respectively.

Table 13

Sources of Labour Productivity Growth in U.S. Industries, 1981-88

			Contributions					
Industry		**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
1	Agriculture	2.29	1.63	0.01	0.06	0.19	0.06	0.35
2	Non-energy Mining	5.48	1.31	0.03	0.38	0.13	0.12	3.51
3	Coal Mining	8.51	3.29	0.01	1.09	0.18	0.21	3.74
4	Crude Petroleum	4.95	0.28	0.14	4.00	0.13	0.03	0.37
5	Construction	–0.11	–0.14	0.00	–0.30	0.11	0.04	0.18
6	Wood and Furniture	1.81	1.35	0.02	–0.26	0.09	0.12	0.49
7	Non-metallic	2.43	1.24	0.02	–0.06	0.15	0.06	1.01
8	Primary Metal	3.02	0.83	0.05	0.25	0.08	0.03	1.78
9	Fabricated Metal	2.38	0.66	0.08	0.16	0.08	0.07	1.33
10	Machinery	1.19	–0.77	0.25	0.41	0.27	–0.04	1.06
11	Computers	20.83	11.53	0.09	–0.15	0.67	–0.45	9.14
12	Electrical Equipment	3.96	1.21	0.20	0.08	0.53	–0.34	2.29
13	Electronic Equipment	9.69	4.72	0.54	1.03	0.49	–0.29	3.21
14	Motor Vehicles	4.85	0.79	0.03	–0.13	0.03	–0.05	4.17
15	Other Trans. Equipment	1.28	0.05	0.28	0.15	0.39	–0.51	0.91
16	Misc. Manufacturing	3.11	1.03	0.25	0.28	0.48	–0.29	1.37
17	Food and Tobacco	2.61	1.04	0.07	0.22	0.06	–0.05	1.26
18	Textiles	3.38	0.71	0.05	0.18	0.18	–0.02	2.28
19	Paper and Allied	2.00	0.20	0.05	0.21	0.14	–0.01	1.41
20	Printing	1.26	–0.43	0.32	0.08	0.39	–0.32	1.21

Table 13 (cont'd)

Sources of Labour Productivity Growth in U.S. Industries, 1981-88

			Contributions				
Industry	**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
21 Chemicals	1.46	0.78	0.12	0.12	0.29	–0.19	0.35
22 Petroleum Refining	5.00	3.76	0.01	0.19	0.05	–0.03	1.01
23 Rubber and Plastics	3.40	1.69	0.06	–0.06	0.17	–0.04	1.59
24 Transportation	1.31	0.82	0.05	–0.39	0.47	–0.32	0.67
25 Communications	2.91	–0.35	0.95	0.96	0.33	–0.20	1.21
26 Electric Utilities	1.62	–0.60	0.43	0.96	0.17	–0.08	0.73
27 Gas Utilities	–3.10	–3.76	0.15	0.34	0.04	–0.02	0.15
28 Wholesale Trade	3.42	1.89	0.69	0.59	0.11	–0.07	0.21
29 Retail Trade	0.81	–0.14	0.21	0.12	0.23	–0.07	0.47
30 FIRE	1.39	–0.75	0.49	0.54	0.28	–0.17	1.00
31 Business Services	–1.73	–1.43	1.54	–0.83	0.14	–0.16	–1.00
32 Health Services	0.41	–0.48	0.37	0.22	0.40	–0.08	–0.03
33 Education, Private	0.52	–1.03	0.03	0.02	1.06	–0.39	0.84
34 Other Services	0.37	0.19	0.03	–0.06	0.17	–0.22	0.26
Industry Group							
IT-producing Industries	7.96	3.26	0.60	0.69	0.46	–0.31	3.26
IT-using Industries	1.19	–0.08	0.52	0.30	0.31	–0.29	0.44
Non-IT Industries	0.64	0.31	0.11	0.03	0.23	–0.08	0.04

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
"LP" and "MFP" are growth rates of labour productivity and multifactor productivity, respectively.

Table 14

Sources of Labour Productivity Growth in U.S. Industries, 1988-95

			Contributions					
	Industry	**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
1	Agriculture	2.74	1.67	0.03	0.08	0.35	–0.08	0.69
2	Non–energy Mining	1.91	1.09	0.18	0.05	0.25	–0.06	0.41
3	Coal Mining	5.17	3.40	0.16	0.77	0.24	0.05	0.55
4	Crude Petroleum	0.88	0.20	0.08	0.01	0.28	–0.09	0.39
5	Construction	–1.54	–1.33	0.06	0.02	0.07	0.08	–0.43
6	Wood and Furniture	0.45	–1.11	0.06	0.00	–0.01	0.16	1.36
7	Non–metallic	0.95	0.38	0.05	–0.07	0.01	0.19	0.40
8	Primary Metal	2.12	0.64	0.04	0.06	0.00	0.08	1.30
9	Fabricated Metal	1.28	0.46	0.10	–0.02	–0.05	0.16	0.63
10	Machinery	2.33	–0.02	0.28	0.26	0.06	0.15	1.61
11	Computers	19.91	10.22	0.07	–0.10	0.03	–0.01	9.70
12	Electrical Equipment	3.55	1.03	0.06	–0.31	0.21	–0.02	2.58
13	Electronic Equipment	15.40	6.82	0.54	1.46	0.11	–0.02	6.49
14	Motor Vehicles	1.19	–0.18	0.03	–0.01	0.04	0.03	1.28
15	Other Trans. Equipment	2.02	0.70	0.10	0.18	0.32	–0.21	0.92
16	Misc. Manufacturing	2.87	–0.48	0.38	0.29	0.51	–0.06	2.24
17	Food and Tobacco	1.14	0.10	0.07	0.12	0.05	0.01	0.78
18	Textiles	2.89	0.57	0.09	0.18	0.15	0.07	1.83
19	Paper and Allied	0.94	–0.65	0.08	0.27	0.13	0.03	1.08
20	Printing	–0.39	–1.21	0.39	0.06	0.40	–0.07	0.04

Table 14 (cont'd)

Sources of Labour Productivity Growth in U.S. Industries, 1988-95

			Contributions					
Industry		**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
21	Chemicals	1.60	–0.14	0.18	0.48	0.23	–0.07	0.90
22	Petroleum Refining	1.42	–0.43	0.03	0.22	0.05	–0.01	1.57
23	Rubber and Plastics	2.27	0.88	0.09	0.17	0.12	0.10	0.91
24	Transportation	0.26	0.36	0.12	–0.38	0.04	0.15	–0.02
25	Communications	2.96	0.13	0.84	0.58	0.29	–0.12	1.25
26	Electric Utilities	2.42	0.85	0.18	0.67	0.21	–0.09	0.60
27	Gas Utilities	–2.06	–0.90	0.35	0.17	0.08	–0.03	–1.74
28	Wholesale Trade	3.04	0.91	0.72	0.19	0.27	0.03	0.93
29	Retail Trade	0.60	–0.18	0.12	0.26	–0.01	0.11	0.31
30	FIRE	2.48	0.37	0.58	0.56	0.30	–0.11	0.79
31	Business Services	1.35	0.54	0.26	0.01	–0.52	0.27	0.79
32	Health Services	–0.72	–1.49	0.19	–0.05	0.10	0.16	0.37
33	Education, Private	–0.90	–1.09	0.04	–0.05	0.32	0.01	–0.13
34	Other Services	1.11	–0.53	0.13	0.37	0.21	–0.03	0.96
Industry Group								
IT-producing Industries		9.56	3.84	0.75	0.77	0.15	–0.04	4.09
IT-using Industries		1.50	0.25	0.40	0.20	0.11	–0.07	0.61
Non-IT Industries		–0.02	–0.35	0.11	–0.04	0.18	0.00	0.09

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
"LP" and "MFP" are growth rates of labour productivity and multifactor productivity, respectively.

Table 15

Sources of Labour Productivity Growth in U.S. Industries, 1995-2000

	Industry	LP	Contributions					
			MFP	IT Capital Deepening	Non-IT Capital Deepening	University Labour Quality Improvement	Non-university Labour Quality Improvement	Intermediate Input Intensity
1	Agriculture	3.23	1.94	0.05	0.36	–0.35	0.23	1.01
2	Non-energy Mining	3.26	0.46	0.20	0.91	–0.25	0.20	1.74
3	Coal Mining	7.49	3.57	0.25	2.14	–0.25	0.27	1.51
4	Crude Petroleum	2.72	0.98	0.20	0.89	–0.24	0.15	0.74
5	Construction	–0.14	–0.95	0.09	0.14	–0.07	0.06	0.60
6	Wood and Furniture	1.92	0.86	0.10	0.07	0.13	0.07	0.68
7	Non-metallic	4.18	0.87	0.23	0.43	0.17	0.04	2.43
8	Primary Metal	3.20	2.50	0.08	0.15	0.08	0.02	0.38
9	Fabricated Metal	4.31	1.63	0.19	0.11	0.13	0.03	2.22
10	Machinery	3.43	0.24	0.56	0.23	0.01	0.05	2.35
11	Computers	31.10	16.76	0.29	0.36	–0.13	0.03	13.81
12	Electrical Equipment	4.17	0.94	0.10	–0.31	0.12	0.00	3.33
13	Electronic Equipment	21.10	11.31	0.77	1.27	0.03	0.00	7.72
14	Motor Vehicles	5.01	0.65	0.06	0.13	0.08	–0.04	4.13
15	Other Trans. Equipment	5.49	0.94	0.31	0.03	0.66	–0.38	3.93
16	Misc. Manufacturing	4.10	–0.24	0.53	0.21	0.74	–0.31	3.18
17	Food and Tobacco	1.50	0.01	0.12	0.32	0.03	0.03	0.98
18	Textiles	5.05	2.13	0.16	0.45	0.09	0.05	2.17
19	Paper and Allied	1.94	1.83	0.12	0.36	0.03	0.05	–0.45
20	Printing	2.08	0.56	0.81	0.14	0.10	–0.04	0.51

Table 15 (cont'd)

Sources of Labour Productivity Growth in U.S. Industries, 1995-2000

		Contributions					
Industry	**LP**	**MFP**	**IT Capital Deepening**	**Non-IT Capital Deepening**	**University Labour Quality Improvement**	**Non-university Labour Quality Improvement**	**Intermediate Input Intensity**
21 Chemicals	2.28	0.50	0.26	0.53	0.08	0.04	0.87
22 Petroleum Refining	4.12	–3.71	0.01	0.13	0.00	0.01	7.69
23 Rubber and Plastics	2.70	1.51	0.19	0.45	0.06	–0.02	0.51
24 Transportation	0.50	–0.22	0.35	0.16	0.01	0.02	0.18
25 Communications	1.54	–1.20	1.03	0.17	0.10	–0.11	1.54
26 Electric Utilities	5.22	2.33	0.29	1.27	0.15	–0.12	1.30
27 Gas Utilities	2.85	0.33	0.48	0.94	0.06	–0.06	1.08
28 Wholesale Trade	2.78	0.08	1.32	0.38	0.01	0.03	0.95
29 Retail Trade	2.59	1.31	0.28	0.25	0.17	–0.22	0.80
30 FIRE	2.75	0.01	1.05	0.09	0.12	–0.07	1.55
31 Business Services	1.62	–1.38	1.33	0.11	–0.08	0.03	1.62
32 Health Services	0.93	–1.07	0.50	0.23	0.47	0.00	0.80
33 Education, Private	–0.78	–1.55	0.07	–0.01	0.71	–0.07	0.08
34 Other Services	2.20	0.51	0.20	0.13	0.19	–0.22	1.39
Industry Group							
IT-producing Industries	12.79	5.88	0.91	0.56	0.02	–0.04	5.45
IT-using Industries	2.59	0.12	0.90	0.17	0.17	–0.13	1.36
Non-IT Industries	1.31	0.11	0.23	0.11	0.15	–0.03	0.74

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.
"LP" and "MFP" are growth rates of labour productivity and multifactor productivity, respectively.

IT-using Industries

In the 1980s, IT using industries, on average, had an equal (in Canada) or higher (in the United States) labour productivity growth than non-IT industries. However, the difference between the two groups increased in the 1990s when labour productivity growth in the IT-using group accelerated. In the United States, labour productivity growth in IT-using industries rose from 1.2 percent per year during 1981-88 to 1.5 percent (1988-95) and 2.6 percent (1995-2000). In Canada the pattern is the same, from 1.2 percent during 1981-88 to 1.8 percent (1988-95) and 2.3 percent (1995-2000), but less pronounced.

The acceleration of labour productivity growth in these industries in the United States in the second half of the 1990s was due to IT capital, university labour and intermediate input deepening. On the other hand, in Canada it was due to an increase in MFP growth, intermediate input and IT capital deepening. In both countries, IT-using industries benefited more than non-IT industries from IT capital deepening in the second half of the 1990s.

In the first half of the 1990s, labour productivity in the Canadian IT-using industries grew at an annual rate of 1.8 percent which was a bit faster than the 1.5 percent in the United States. This difference was mainly due to a greater increase in university labour input intensity in Canada. However, this was reversed in the second half of the 1990s when the U.S. IT-using industries saw a higher productivity growth rate. This was mainly due to an accelerated IT capital contribution in the United States. Of the 2.6 percent growth rate of labour productivity, IT capital deepening contributed 0.9 percentage points, while in Canada it contributed 0.4 percentage points out of 2.3 percent.

Aggregate Growth and Sector Contributions

Sources of Aggregate Output (Value-added) Growth

We now turn to the economy as a whole. The growth in value added for the entire business sector, aggregated over the 34 industries, is given in Equations (4) and (5). This bottom-up result is given in the first row of Table 16. These estimates are generally consistent with those estimates of Statistics Canada that come from a top-down approach.[23] These two estimates are reported in the bottom part of Table 16, under "Addendum". The difference between the two estimates, labelled as reallocation of value added, is relatively small.

Table 16

Sources of Aggregate Value-added Growth in Canada and the United States

	Canada			United States		
	1981-88	**1988-95**	**1995-2000**	**1981-88**	**1988-95**	**1995-2000**
			Contributions			
Value Added	3.28	1.82	5.00	3.62	2.38	4.54
Capital Input	1.27	0.81	1.62	1.55	1.09	2.13
IT	0.35	0.33	0.58	0.61	0.52	1.15
Non-IT	0.92	0.48	1.04	0.94	0.57	0.98
Labour Input	1.36	0.56	2.28	1.49	1.15	1.60
University	0.45	0.57	0.87	0.93	0.60	0.82
Non-university	0.91	–0.01	1.41	0.56	0.55	0.78
MFP	0.65	0.45	1.11	0.58	0.14	0.81
			Growth Rates			
Value Added	3.28	1.82	5.00	3.62	2.38	4.54
Capital Input	3.21	2.14	4.10	4.53	3.20	5.97
IT	15.86	12.69	17.25	19.60	11.32	20.11
Non-IT	2.48	1.34	2.87	3.01	1.93	3.27
Labour Input	2.28	0.92	3.79	2.27	1.74	2.49
University	5.76	4.71	6.18	5.01	2.67	3.47
Non-university	1.79	0.03	3.06	1.24	1.28	1.91
MFP	0.65	0.45	1.11	0.58	0.14	0.81
			Addendum			
Bottom-up	3.28	1.82	5.00	3.62	2.38	4.54
Top-down	3.25	1.50	4.86	3.70	2.61	4.55
Reallocation of Value Added	0.03	0.32	0.14	-0.08	–0.23	–0.05
Hours worked	1.95	0.27	3.06	2.00	1.41	2.23

Economic growth accelerated in the second half of the 1990s in both countries. The acceleration was more pronounced in Canada, from 1.8 percent per year to 5.0 percent, versus 2.4 percent to 4.5 percent for the United States. In the 1980s, however, the Canadian business sector grew at 3.3 percent compared to 3.6 percent in the United States.

The more sizable differences are in factor contributions. The largest contributor in Canada during the boom period (1995-2000) was labour, which accounted for 2.3 out of the 5.0 percentage points, while capital contributed only 1.6 percentage points. On the other side of the border, capital and labour contributed 2.1 and 1.6 percentage points to the 4.5 percent aggregate growth rate, respectively. The difference in IT capital contribution is even more pronounced. The extremely rapid growth in IT investment in the United States produced a 1.2 percentage point contribution, while, in Canada, it was only 0.6 percentage points. The difference in labour contribution is entirely due to the higher growth rate of non-university educated labour in Canada. We should note, however, that the less-educated labour force expanded greatly during the boom period in both countries. In sum, the acceleration of value-added growth in Canada in the second half of the 1990s was mainly driven by non-IT capital and non-university labour while in the United States, it was mainly due to the accumulation of both IT and non-IT capital as well as an increase in MFP growth (Figure 1).

We now turn to Equation (4) for estimating individual industry contributions to aggregate growth. An industry contribution is the product of its share in total value added and its value-added growth rate. Industry shares in total value added are displayed in Table 17. As before, we concentrate on the three industry groups: IT-producing, IT-using, and non-IT industries. In both countries, the value-added share of the IT-producing group was essentially flat over the period 1981-2000, while the share of the IT-using group increased at the expense of the non-IT group. This is essentially due to the expansion of FIRE and business services industries, with contraction in mining, construction and agriculture. In recent years, the Canadian economy is concentrated relatively less in IT-producing and IT-using industries and more in non-IT industries, compared to the United States.

Figure 2 gives the contributions of three major groups to aggregate output growth, while Figures 6 through 8 give the contributions of each of the 34 industries for the three sub-periods: 1981-88, 1988-95, and 1995-2000. All three groups contributed to the acceleration of output growth in both countries from the first half to the second half of the 1990s. Nevertheless, most of the acceleration in Canada was from non-IT industries, while in the United States it was mainly from IT-using industries.

Figure 1

Sources of the Accelaration in Aggregate Value-added Growth Between 1988-1995 and 1995-2000

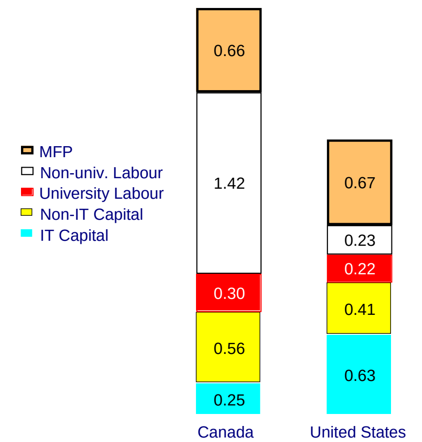
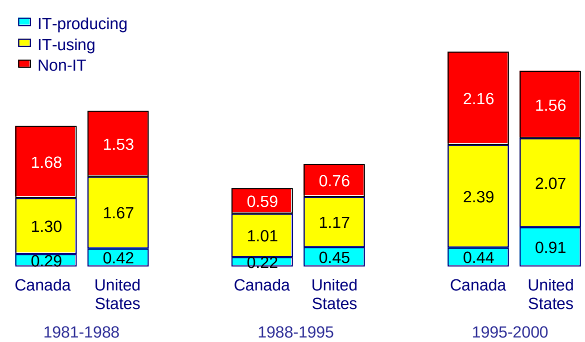


Figure 2

Industry Contributions to Aggregate Value-added Growth in Canada and the United States, 1981-2000



Note: IT producing industries are computer, electronic equipment and communications. IT-intensive using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services.

Figure 3

Sources of the Acceleration in Aggregate Labour Productivity Growth between 1988-1995 and 1995-2000

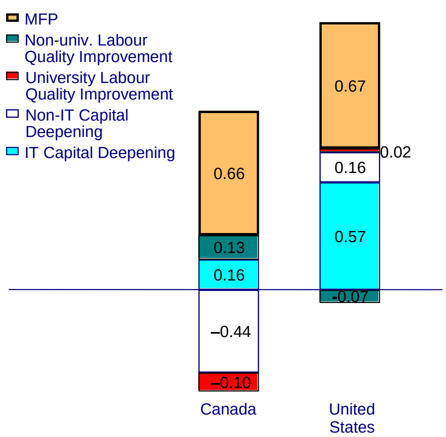
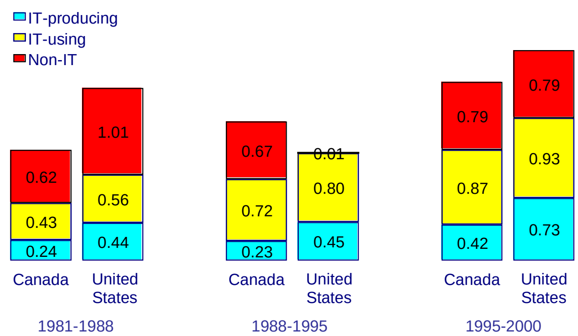


Figure 4

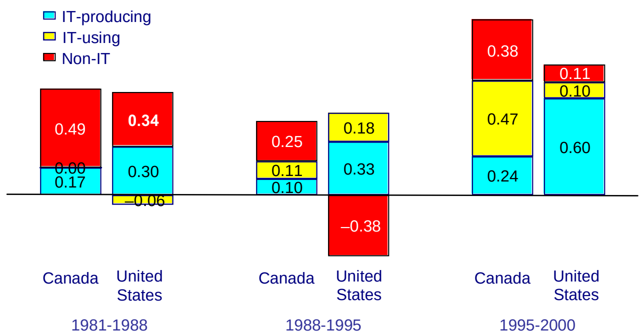
Industry Contributions to Aggregate Labour Productivity Growth in Canada and the United States, 1981-2000



Note: Labour productivity is defined as value added per hour.
IT producing industries are computer, electronic equipment and communications.
IT-intensive using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services.

Figure 5

Industry Contributions to Aggregate MFP Growth in Canada and the United States, 1981-2000



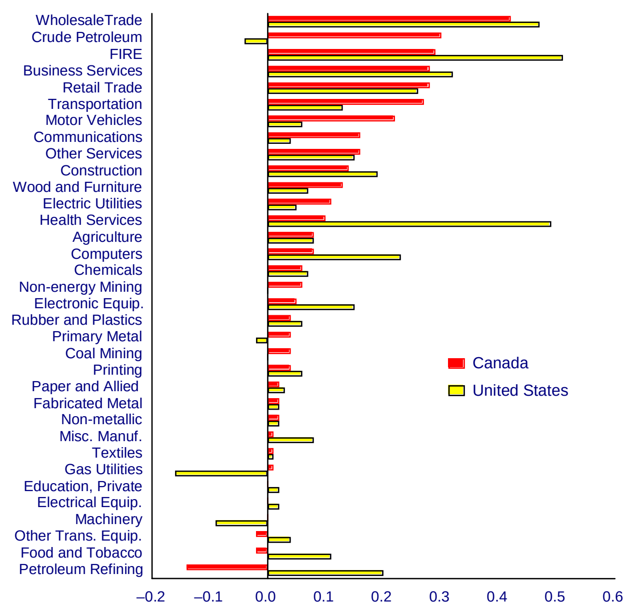
Note: IT producing industries are computer, electronic equipment and communications.
IT-intensive using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services.

If we examine detailed industry contributions in Figures 6 through 8, we see that the top four contributors to aggregate growth in Canada during the boom period are all IT-using industries — business services, FIRE, wholesale trade, and retail trade. In the United States the top three are FIRE, business services, communication and electronic equipment, while the fourth highest is a non-IT industry, health services.

Table 18 gives the change in hours worked for the 34 industries during the three periods. During 1995-2000, Canada has higher employment growth than the United States in almost all sectors, the main exceptions being communications, agriculture, construction and FIRE.

Figure 6

Contributions to Aggregate Value-added Growth by Industry in Canada and the United States, 1981-1988

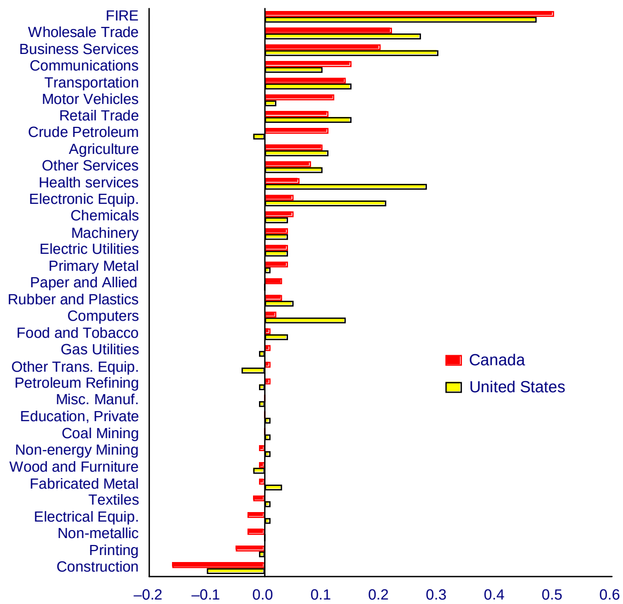


Sources of Aggregate Labour Productivity Growth

The results on sources of aggregate labour productivity, as described in Equation (9), are reported in Table 19. In the second half of 1990s, aggregate labour productivity in Canada grew at an annual rate of 1.9 percent, compared to 2.3 percent in the United States. In Canada, the largest contributor was MFP growth, 1.1 percentage points, with a modest 0.4 percent each for capital deepening and labour quality. In the United States, the sources of improvements in labour productivity were different: IT-capital deepening alone accounted for 1.0 percentage points out of the 2.3 percent while the contribution from labour was held back by the surge in employment of less educated workers. Both countries saw a revival of MFP growth. MFP growth contributed 0.8 percentage points to the U.S. labour productivity growth. IT capital contributed more than non-IT capital in both countries, and university labour contributed more than non-university labour.

Figure 7

Contributions to Aggregate Value-added Growth by Industry in Canada and the United States, 1988-1995

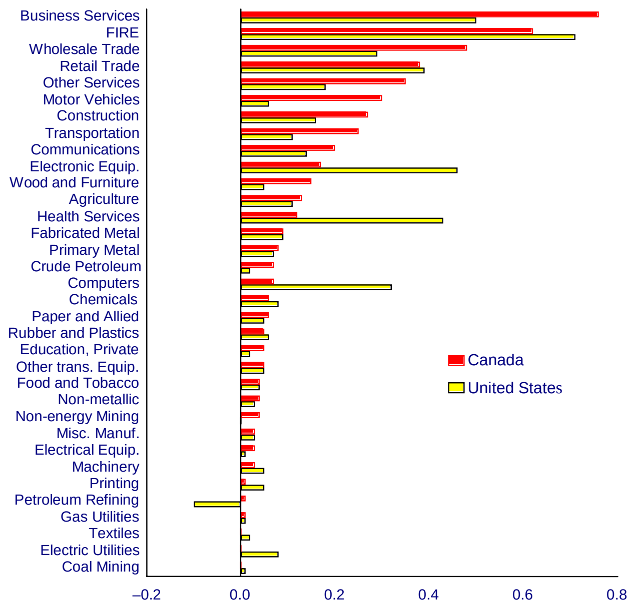


The acceleration of aggregate labour productivity growth in Canada in the latter half of the 1990s was mainly due to the serge in MFP growth by 0.7 percentage points (Figure 3). The labour productivity growth in the United States accelerated dramatically, from 1.0 percent in the first half to 2.3 percent per year in the second half of the 1990s. Greater IT-capital deepening and the increased MFP growth contributed equally to the acceleration of labour productivity growth. Furthermore, non-IT capital deepening did not slow down as in Canada.

Equation (10) shows how aggregate labour productivity growth is made up of industry contributions and reallocation of hours. The contributions of three major industry groups are summarized in Figure 4. The acceleration of aggregate labour productivity growth in Canada in the second half of the 1990s was driven mainly by IT-producing industries and to a lesser extent, by IT-using and non-IT industries.

Figure 8

Contributions to Aggregate Value-added Growth by Industry in Canada and the United States, 1995-2000



In the United States, the acceleration was mainly driven by the increased contribution from non-IT industries. However, most of the increased contribution was the recovery of the drop in the first half of the 1990s from that in 1980s. Unlike non-IT industries, the contribution from both IT-producing and IT-using industries accelerated over those three periods in both countries.

Table 17

Industry Shares of Value Added in Canada and the United States

		Canada				United States			
	Industry	**1981**	**1988**	**1995**	**2000**	**1981**	**1988**	**1995**	**2000**
1	Agriculture	0.044	0.029	0.028	0.020	0.035	0.024	0.024	0.025
2	Non-energy Mining	0.030	0.028	0.020	0.016	0.005	0.003	0.003	0.002
3	Coal Mining	0.002	0.003	0.002	0.001	0.007	0.004	0.003	0.002
4	Crude Petroleum	0.059	0.029	0.031	0.034	0.048	0.015	0.010	0.009
5	Construction	0.101	0.087	0.067	0.068	0.068	0.065	0.052	0.053
6	Wood and Furniture	0.026	0.026	0.029	0.031	0.011	0.012	0.011	0.010
7	Non-metallic	0.008	0.009	0.006	0.006	0.009	0.008	0.006	0.007
8	Primary Metal	0.019	0.019	0.016	0.016	0.014	0.010	0.009	0.008
9	Fabricated Metal	0.017	0.015	0.013	0.015	0.021	0.016	0.015	0.016
10	Machinery	0.015	0.013	0.015	0.015	0.031	0.020	0.020	0.020
11	Computers	0.002	0.003	0.001	0.001	0.007	0.006	0.005	0.005
12	Electrical Equipment	0.010	0.008	0.006	0.005	0.012	0.010	0.008	0.008
13	Electronic Equipment	0.006	0.008	0.009	0.011	0.011	0.012	0.014	0.017
14	Motor Vehicles	0.017	0.024	0.030	0.028	0.011	0.011	0.011	0.010
15	Other Trans. Equipment	0.010	0.008	0.011	0.011	0.018	0.016	0.013	0.011
16	Misc. Manufacturing	0.007	0.007	0.007	0.007	0.020	0.020	0.018	0.016
17	Food and Tobacco	0.032	0.032	0.032	0.030	0.026	0.026	0.025	0.022
18	Textiles	0.017	0.014	0.011	0.010	0.017	0.012	0.009	0.007
19	Paper and Allied	0.022	0.025	0.027	0.017	0.011	0.011	0.011	0.009
20	Printing	0.013	0.015	0.014	0.014	0.017	0.019	0.017	0.017
21	Chemicals	0.017	0.023	0.023	0.018	0.027	0.025	0.025	0.023
22	Petroleum Refining	0.005	0.003	0.003	0.002	0.007	0.005	0.004	0.004

Table 17 (cont'd)

Industry Shares of Value Added in Canada and the United States

	Canada				United States			
Industry	**1981**	**1988**	**1995**	**2000**	**1981**	**1988**	**1995**	**2000**
23 Rubber and Plastics	0.007	0.007	0.009	0.009	0.009	0.010	0.011	0.010
24 Transportation	0.066	0.061	0.061	0.062	0.045	0.040	0.039	0.033
25 Communications	0.029	0.029	0.031	0.027	0.027	0.027	0.027	0.029
26 Electric Utilities	0.031	0.037	0.040	0.033	0.024	0.026	0.024	0.021
27 Gas Utilities	0.004	0.005	0.005	0.004	0.006	0.006	0.004	0.003
28 Wholesale Trade	0.059	0.070	0.070	0.072	0.076	0.071	0.070	0.067
29 Retail Trade	0.078	0.082	0.072	0.077	0.092	0.089	0.085	0.083
30 FIRE	0.110	0.125	0.137	0.142	0.118	0.149	0.159	0.166
31 Business Services	0.042	0.054	0.063	0.083	0.034	0.056	0.067	0.084
32 Health Services	0.023	0.029	0.033	0.032	0.092	0.125	0.145	0.145
33 Education, Private	0.001	0.001	0.001	0.003	0.007	0.008	0.009	0.010
34 Other Services	0.070	0.074	0.077	0.077	0.038	0.044	0.048	0.049
Industry Group								
IT-producing Industries	0.038	0.039	0.041	0.040	0.044	0.045	0.046	0.051
IT-using Industries	0.344	0.382	0.394	0.427	0.417	0.449	0.457	0.472
Non-IT Industries	0.618	0.579	0.565	0.533	0.539	0.506	0.497	0.477
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.

Table 18

Growth in Hours Worked in Canadian and U.S. Industries, 1981-2000

		Canada			United States		
	Industry	**1981-88**	**1988-95**	**1995-2000**	**1981-88**	**1988-95**	**1995-2000**
1	Agriculture	–0.13	–1.07	–3.52	–1.53	–0.01	0.10
2	Non-energy Mining	–2.21	–0.03	3.13	–3.92	0.42	–1.47
3	Coal Mining	–0.50	0.08	–4.69	–6.41	–4.03	–6.69
4	Crude Petroleum	5.26	–1.83	1.68	–7.40	–2.15	–1.61
5	Construction	1.82	–1.26	3.29	3.42	0.89	4.62
6	Wood and Furniture	1.83	–0.88	3.37	2.34	0.17	1.33
7	Non-metallic	0.30	–3.59	2.15	–0.31	–0.49	1.43
8	Primary Metal	–1.84	–3.43	1.42	–4.91	–1.12	–0.16
9	Fabricated Metal	0.23	–1.55	4.72	–1.01	0.32	1.28
10	Machinery	1.64	–0.88	4.91	–2.94	0.64	0.45
11	Computers	1.47	–1.90	1.73	1.60	–3.66	0.40
12	Electrical Equipment	–2.20	–6.16	3.15	–1.52	–1.32	–0.61
13	Electronic Equipment	4.48	–1.40	3.93	0.81	–0.86	2.37
14	Motor Vehicles	4.88	0.42	4.74	1.73	2.08	1.06
15	Other Trans. Equipment	–0.13	–2.00	3.54	2.01	–5.10	0.50
16	Misc. Manufacturing	1.53	–1.38	3.57	0.55	–1.63	0.08
17	Food and Tobacco	–0.01	–1.38	2.07	–0.78	0.43	0.03
18	Textiles	–0.29	–5.09	1.77	–2.01	–1.76	–6.12
19	Paper and Allied	–0.46	–2.15	0.87	0.72	0.29	–1.15
20	Printing	3.28	–1.21	3.55	2.90	0.22	–0.10
21	Chemicals	0.91	–1.23	3.54	–0.29	–0.13	–0.08
22	Petroleum Refining	–6.06	–2.77	6.27	–2.91	–1.14	–2.61

Table 18 (cont'd)

Growth in Hours Worked in Canadian and U.S. Industries, 1981-2000

	Canada			United States		
Industry	**1981-88**	**1988-95**	**1995-2000**	**1981-88**	**1988-95**	**1995-2000**
23 Rubber and Plastics	3.45	0.16	4.79	2.39	1.86	0.75
24 Transportation	1.08	1.44	2.45	2.08	3.14	2.31
25 Communications	0.53	0.26	–0.49	–1.41	0.80	4.87
26 Electric Utilities	0.55	1.40	0.50	0.62	–1.12	–2.35
27 Gas Utilities	2.56	3.56	–2.47	–1.64	–0.53	–3.50
28 Wholesale Trade	1.74	1.34	5.12	1.52	0.69	1.39
29 Retail Trade	2.39	0.46	1.22	2.42	1.25	1.58
30 FIRE	2.27	0.72	1.66	3.06	0.44	2.50
31 Business Services	5.24	2.80	8.77	7.90	4.03	6.53
32 Health Services	7.01	3.80	6.66	3.66	3.64	2.75
33 Education, Private	8.31	4.83	17.54	2.83	2.75	3.65
34 Other Services	2.83	1.14	2.11	3.44	1.92	2.22
Industry Group						
IT-producing Industries	1.69	–0.40	1.02	–0.14	–0.52	3.43
IT-using Industries	2.54	0.81	3.95	2.59	1.13	2.43
Non-IT Industries	1.56	–0.08	2.45	1.62	1.74	2.00
Aggregate	1.95	0.27	3.06	2.00	1.41	2.23

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.

Table 19

Sources of Aggregate Labour Productivity Growth in Canada and the United States

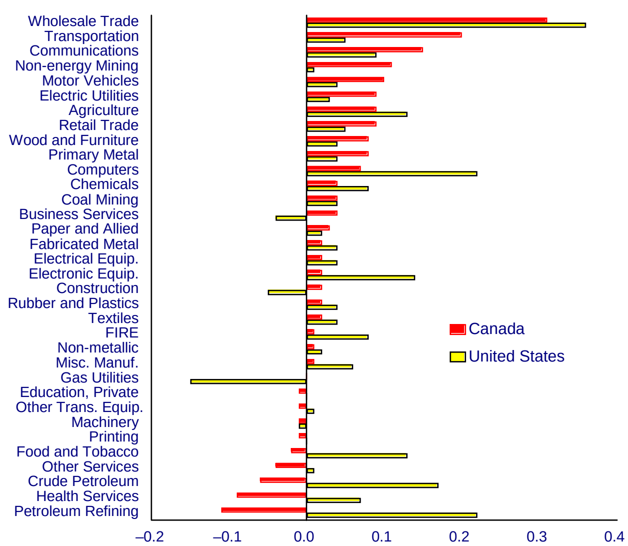
	Canada			United States		
	1981-88	**1988-95**	**1995-2000**	**1981-88**	**1988-95**	**1995-2000**
			Contributions			
Labour Productivity	1.33	1.55	1.93	1.62	0.97	2.31
Capital Deepening	0.48	0.69	0.41	0.87	0.60	1.34
IT	0.30	0.32	0.48	0.54	0.45	1.02
Non-IT	0.18	0.37	–0.07	0.33	0.15	0.31
Labour Quality Improvement	0.20	0.41	0.43	0.18	0.22	0.17
University	0.29	0.54	0.44	0.54	0.28	0.30
Non-university	–0.09	–0.13	0.00	–0.36	–0.06	–0.13
MFP	0.65	0.45	1.11	0.58	0.14	0.81
			Growth Rates			
Labour Productivity	1.33	1.55	1.93	1.62	0.97	2.31
Capital Deepening	1.26	1.87	1.04	2.53	1.79	3.74
IT	13.91	12.42	14.18	17.60	9.91	17.88
Non-IT	0.53	1.07	–0.19	1.02	0.52	1.04
Labour Quality Improvement	0.33	0.64	0.72	0.27	0.34	0.26
University	3.80	4.43	3.11	3.01	1.27	1.24
Non-university	–0.16	–0.25	0.00	–0.75	–0.13	–0.32
MFP	0.65	0.45	1.11	0.58	0.14	0.81
			Addendum			
Labour Productivity	1.33	1.55	1.93	1.62	0.97	2.31
Industry Contribution	1.30	1.62	2.08	2.01	1.26	2.46
Reallocation of Hours	0.03	–0.08	–0.15	–0.39	–0.29	–0.15

Note: Aggregate labour productivity is defined as aggregate value added per hour worked.

In Figures 9 through 11, we give the contributions for all 34 industries. In the 1980s the top five contributors to Canadian aggregate labour productivity growth were: wholesale trade; transportation; communications; non-energy mining; and motor vehicles. By the late 1990s, the top sectors were FIRE, retail trade, communications, agriculture and other services. Health services was the big laggard in all periods. The industry picture in the United States is somewhat different where the biggest contributors to the productivity revival were: communication and electronic equipment; computers; FIRE; retail trade; and wholesale trade.

Figure 9

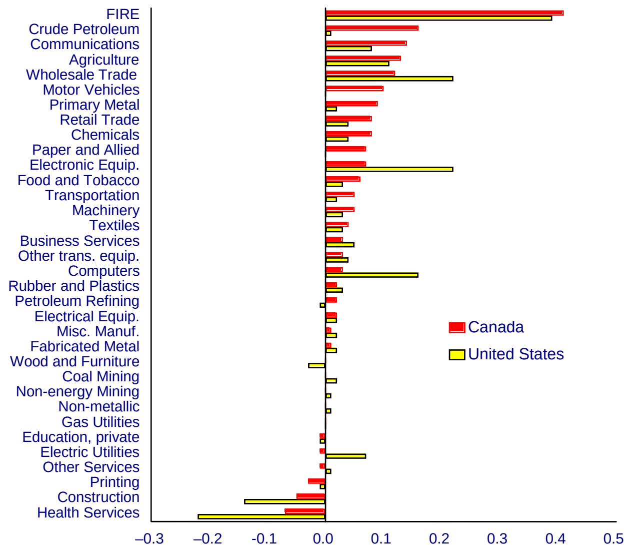
Contributions to Aggregate Labour Productivity Growth by Industry in Canada and the United States, 1981-1988



Note: Labour productivity is defined as value added per hour worked.

Figure 10

Contributions to Aggregate Labour Productivity Growth by Industry in Canada and the United States, 1988-1995



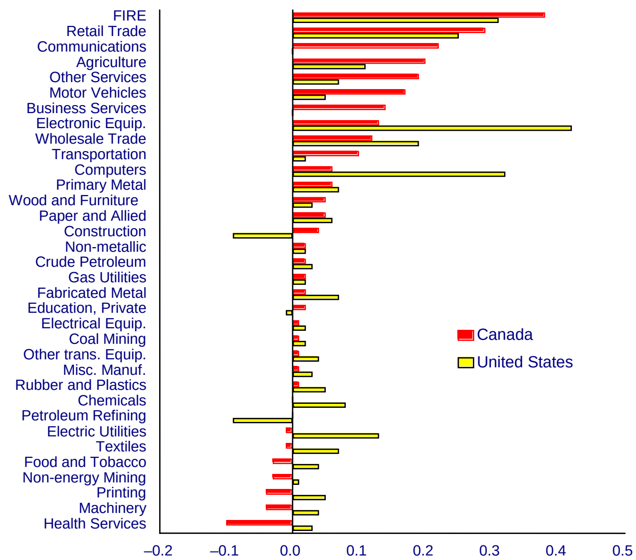
Note: Labour productivity is defined as value added per hour worked.

Sources of Aggregate MFP Growth

Aggregate MFP growth accelerated in both countries in the latter half of the 1990s. In Canada, it increased from 0.5 percent per year during 1988-95 and 1.1 percent during 1995-2000. In the United States, it increased from 0.1 to 0.8 percent.[24]

Figure 11

Contributions to Aggregate Labour Productivity Growth by Industry in Canada and the United States, 1995-2000



Note: Labour productivity is defined as value added per hour worked.

We now look at individual industry contributions to aggregate MFP growth. According to the Domar weighting scheme, shown in Equation (12), each industry contribution is calculated as the product of its MFP growth and the Domar weight. The Domar weights, essentially industry gross output divided by aggregate gross domestic product, are given in Table 20. Sectors with the biggest Domar weights are FIRE, other services, construction, and motor vehicles. In Figure 5, we summarize the contributions of the three major industry groups, and in Figures 12 through 14 we give the contributions of all 34 industries.

Table 20

Domar Weights in Canadian and U.S. Industries, 1982-2000

		Canada				United States			
	Industry	**1982**	**1988**	**1995**	**2000**	**1982**	**1988**	**1995**	**2000**
1	Agriculture	0.094	0.067	0.065	0.054	0.093	0.057	0.051	0.057
2	Non-energy Mining	0.048	0.041	0.033	0.027	0.047	0.005	0.005	0.028
3	Coal Mining	0.004	0.004	0.003	0.002	0.004	0.007	0.004	0.002
4	Crude Petroleum	0.074	0.046	0.046	0.053	0.076	0.031	0.020	0.054
5	Construction	0.237	0.212	0.173	0.156	0.232	0.151	0.122	0.166
6	Wood and Furniture	0.059	0.067	0.075	0.076	0.058	0.030	0.029	0.080
7	Non-metallic	0.018	0.019	0.013	0.013	0.018	0.016	0.013	0.014
8	Primary Metal	0.064	0.061	0.056	0.049	0.063	0.034	0.030	0.052
9	Fabricated Metal	0.044	0.039	0.031	0.034	0.043	0.039	0.034	0.036
10	Machinery	0.032	0.028	0.031	0.031	0.031	0.041	0.042	0.032
11	Computers	0.006	0.007	0.011	0.007	0.005	0.018	0.017	0.008
12	Electrical Equipment	0.024	0.021	0.015	0.014	0.024	0.023	0.021	0.015
13	Electronic Equipment	0.012	0.016	0.023	0.033	0.012	0.022	0.028	0.035
14	Motor Vehicles	0.077	0.100	0.134	0.161	0.075	0.053	0.054	0.175
15	Other Trans. Equipment	0.020	0.018	0.021	0.027	0.020	0.034	0.025	0.028
16	Misc. Manufacturing	0.018	0.016	0.015	0.015	0.018	0.036	0.033	0.016
17	Food and Tobacco	0.134	0.110	0.102	0.091	0.131	0.088	0.079	0.097
18	Textiles	0.041	0.035	0.026	0.022	0.040	0.034	0.028	0.023
19	Paper and Allied	0.058	0.059	0.058	0.045	0.057	0.029	0.027	0.048
20	Printing	0.027	0.029	0.027	0.026	0.026	0.036	0.031	0.028

Table 20 (cont'd)

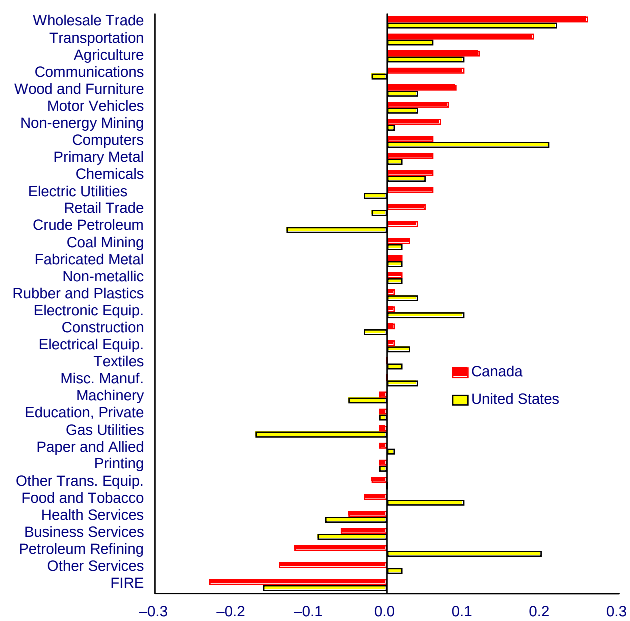
Domar Weights in Canadian and U.S. Industries, 1982-2000

	Canada				United States			
Industry	**1982**	**1988**	**1995**	**2000**	**1982**	**1988**	**1995**	**2000**
21 Chemicals	0.058	0.054	0.054	0.044	0.056	0.061	0.059	0.047
22 Petroleum Refining	0.096	0.036	0.032	0.029	0.093	0.034	0.026	0.032
23 Rubber and Plastics	0.019	0.020	0.022	0.023	0.018	0.023	0.024	0.024
24 Transportation	0.123	0.115	0.113	0.112	0.121	0.076	0.076	0.117
25 Communications	0.038	0.039	0.044	0.042	0.038	0.048	0.048	0.043
26 Electric Utilities	0.041	0.044	0.050	0.042	0.042	0.041	0.036	0.042
27 Gas Utilities	0.005	0.006	0.006	0.005	0.005	0.022	0.014	0.005
28 Wholesale Trade	0.087	0.099	0.107	0.114	0.086	0.106	0.107	0.119
29 Retail Trade	0.114	0.118	0.113	0.116	0.112	0.155	0.148	0.121
30 FIRE	0.177	0.204	0.229	0.235	0.176	0.229	0.241	0.244
31 Business Services	0.060	0.072	0.093	0.127	0.059	0.075	0.093	0.133
32 Health Services	0.031	0.037	0.044	0.043	0.030	0.180	0.213	0.045
33 Education, Private	0.002	0.002	0.002	0.004	0.002	0.015	0.016	0.004
34 Other Services	0.119	0.124	0.135	0.142	0.117	0.079	0.087	0.149
Industry Group								
IT-producing Industries	0.056	0.062	0.078	0.082	0.088	0.088	0.092	0.105
IT-using Industries	0.559	0.607	0.651	0.706	0.706	0.735	0.740	0.772
Non-IT Industries	1.448	1.300	1.274	1.227	1.298	1.105	1.049	1.002
Total	2.062	1.968	2.003	2.014	2.092	1.929	1.882	1.879

Note: IT-producing industries are computer, electronic (including communication) equipment and communications (services). IT-using industries are machinery, electrical equipment, printing and publishing, other transportation equipment, miscellaneous manufacturing, wholesale trade, retail trade, finance, insurance and real estate, and business services. Non-IT industries are the remaining industries.

Figure 12

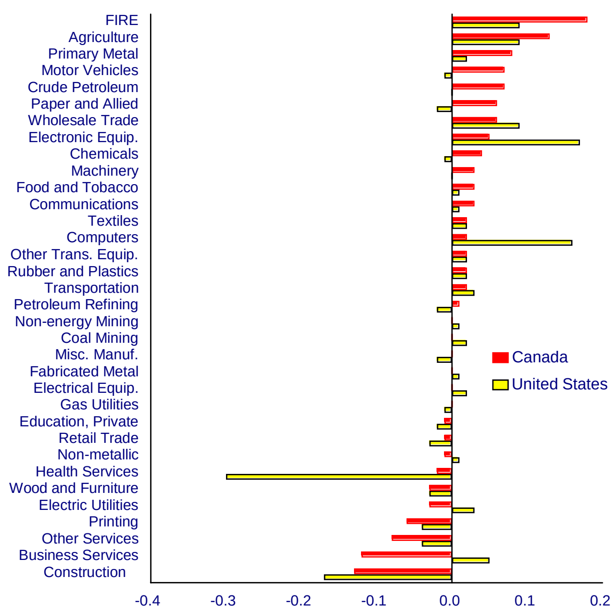
Contributions to Aggregate MFP Growth by Industry in Canada and the United States, 1981-1988



In Canada, the aggregate MFP growth in the latter half of the 1990s was mainly due to IT-using and non-IT industries (76.6 percent), while in the United States IT-producing industries contributed 0.6 percentage points of 0.8 percent growth. The larger contributions from IT-using and non-IT industries in Canada were due to their larger Domar weights, not to their higher growth rates.[25] On the other hand, the small Domar weight of 0.08 for IT-producing industries multiplied by their high MFP growth rates (2.9 percent per year on average) results in a very small contribution.

Figure 13

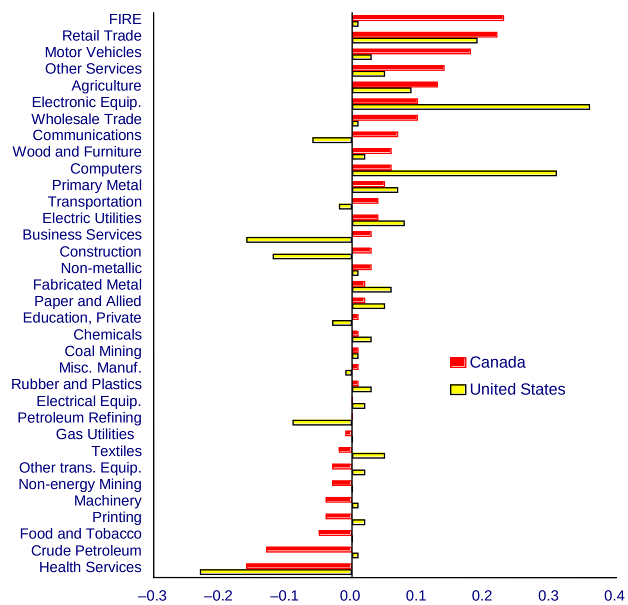
Contributions to Aggregate MFP Growth by Industry in Canada and the United States, 1988-1995



For the United States, however, the larger contribution from IT-producing industries was due to the extraordinary MFP growth (5.9 percent per year on average). The MFP growth was a mere 0.1 percent in both IT-using and non-IT industries.

Figure 14

Contributions to Aggregate MFP Growth by Industry in Canada and the United States, 1995-2000



Turning to the detailed industry contributions in Figures 12 through 14, the biggest contributors to Canadian business MFP growth in the 1980s were: wholesale trade; transportation; agriculture; communications; and wood and furniture. By the latter half of the 1990s, they were FIRE, retail trade, motor vehicles, other services and agriculture. On the other hand, the biggest contributors to the MFP growth revival in the United States were: communication and electronic equipment; computers; retail trade; agriculture; and electric utilities.

Conclusions

The main objective of this study has been to provide an in-depth analysis of the sources of output and labour productivity growth in Canadian and U.S. industries, using newly developed comparable industry data for 34 industries in Canada and the United States. The focus of this study has been on examining the role of information and communication technologies and human capital in labour productivity growth, especially in its acceleration during the latter half of the 1990s.

Several important conclusions emerge from our empirical findings. Computers and electronic equipment industries registered very strong growth in output, labour productivity and MFP in both countries during the past 20 years. Growth in MFP and intermediate input accounted for over three quarters of the growth in output and labour productivity in these two industries in both countries.

The acceleration of growth in real value-added in the United States in the latter half of the 1990s was largely due to the accumulation of IT capital and the increased use of university-trained labour. On the other hand, in Canada, accumulation of non-IT capital and the increased use of non-university labour were responsible for the resurgence of value-added growth in the business sector. The growth in value added in the United States in the second half of the 1990s was more concentrated in IT-producing industries while in Canada all the three major industry groups contributed to the growth revival.

The IT capital was the driving force behind the revival of labour productivity growth in the United States and its impact was widespread across many industries. On the other hand, IT capital made only a small contribution to the productivity growth resurgence in Canada. Close to 70 percent of labour productivity growth in the United States in the second half of the 1990s was due to IT-producing and IT-using industries. They accounted for only about 60 percent of the business sector productivity growth in Canada. In addition, the contribution of IT-producing industries in Canada was significantly smaller than in the United States.

Endnotes

1 The share of hours worked by workers with at least a university degree in Canada increased from 11 percent in 1990 to 16 percent in 2000. In the United States, it increased from 24 to 27 percent.

2 See Harchaoui et al. (2002), Rao and Tang (2001), Crawford (2002), and Robidoux and Wong (2003) for Canada, and Jorgenson, Ho, and Stiroh (2002) and Stiroh (2002) for the United States.

3 In many previous studies involving Canada-U.S. comparisons, e.g. Gu and Ho (2000) and Rao and Tang (2001), these industries are combined with one of the three sectors: machinery, electrical equipment, and services.

4 For the purpose of policy analysis, in this study, we group communication services with IT-producing industries, which is consistent with the OECD definition.

5 Harchaoui, Tarkhani, and Khanam (2004) and Gu and Wang (2004) in this volume focus on the aggregate and detailed Canadian industries, respectively.

6 There have been a number of significant developments since those earlier studies. First, software purchases are now treated as investments, as final demand rather than as intermediate input in the previous system. The new treatment significantly increases output and capital stock in terms of both levels and growth rates. Second, the earlier work only covers the period 1961-95, before the dramatic growth resurgence in the second half of the 1990s that is captured here.

7 We define gross output as sales plus changes in the inventories, the output of all firms in the industry. This is different from the sectoral output concept used by the U.S. Bureau of Labor Statistics in their productivity estimates, where transactions within an industry [the diagonal elements of the input/output (IO) matrix] are excluded. Statistics Canada produces estimates using gross output, value added and the sectoral output concept.

8 As many have pointed out, this MFP growth term is a residual that captures a variety of other factors, including economies of scale, unaccounted for inputs (such as managerial talent and organizational structure), and measurement errors (in both output and inputs).

9 If Equation (3) only used total labour instead of university and non-university, then $l_i = L_i \,/\, H_i$ is simply the index of compositional change (or labour quality index in the Jorgenson terminology). That is, labour productivity change is MFP change plus input deepening plus labour quality change. Here, l_i^{BA} and l_i^{NBA} represents the combination of changes in the composition of university hours,

composition of non-university hours, and the reallocation of hours between these two types.

10 The quantity of intermediate input is calculated as a translog index of the three components.

11 In the official estimates of Statistics Canada, gender is not used as a separate classification strata and therefore the estimates produced here will differ from those in Gu et al. (2003). Gender has been used for this project for purposes of compatibility to the Jorgenson database.

12 Here we consider only the private business sector for our 34 industries. Unlike Jorgenson, Ho, and Stiroh (2002), we do not include the government and household sectors.

13 This is unlike Jorgenson, Gollop, and Fraumeni (1987) which defines aggregate V as a simple linear sum of V_i's.

14 This differs from the treatment in Jorgenson, Ho, and Stiroh (2002) which constructs aggregate inputs ignoring the industry dimension. That approach generates a reallocation term in the decomposition of aggregate MFP. Our treatment in Equation (9) is dictated by the fact that this project did not have detailed capital data by asset types. Statistics Canada provided the Capital Input Series Kit already aggregated over asset types.

15 The P-level has a total of 123 industries. The study presented in this chapter excludes owner-occupied dwellings (P116), though they are included in the chapter by Harchaoui, Tarkhani, and Khanam in this volume. It should be noted that the data use the final IO tables up until 1997 that are constructed on an Standard Industrial Classification (SIC) basis and a set of tables for the period 1997 to 2000 that were constructed just for this project on an SIC basis (the official tables for the latter period are produced only for the new NAICS) classification system.

16 In 2000, IT investment in Canada was CAN$34 billion in current prices, representing 37 percent of the overall machinery and equipment (M&E) investment, compared to less than CAN$6 billion or 19 percent of the overall M&E investment in 1981. Similar changes occurred in the United States. In 2000, IT investment was US$424 billion in current dollars, compared to US$62 billion in 1981. Its share of the overall M&E investment increased to 39 percent in 2000 from 21 percent in 1981.

17 For instance, the fall in computer prices in European countries in the early 1990s ranged from 10 to 47 percent (Triplett, 2001, p.4).

18 To implement the match model technique, a statistical agency chooses a sample of products (models) of a type. It collects an initial period price for each of the products selected. It then collects in the second period the price for the exact same products that were selected in the initial period. The price index is computed by matching the price for the second period with initial price, observation-by-observation or "model-by-model" (for details, see Triplett). The hedonic regression technique regresses the prices of a product on a list of product characteristics that affects product quality. As an example, a list of characteristics for a computer includes speed, often measured in MIPS, and memory size, often measured in megabytes, among other technical features and specifications. The constant-quality price index is the change in price in year over year after controlling for the characteristics. Unlike the match model technique, the hedonic regression technique will use all observations from all periods, including the ones that disappeared or were newly introduced. The hedonic regression technique has become popular and gained wide acceptance in statistics agencies worldwide in estimating price indexes for IT products. Nevertheless, it has been criticized for lack of theoretical foundation, especially for its function forms, lack of transparency, and its subjectivities in selecting the quantities of characteristics.

19 These depreciation rates have been used to derive the official MFP estimates for the business sector in Canada.

20 Note, however, that the educational classification is not entirely consistent over time in both countries. The educational classification in the Labour Force Survey changed in 1990 in Canada (Gu and Maynard, 2001). A similar change also took place in the United States in the Current Population Survey in 1992 and in the Census of Population in 1990 (Jorgenson, Ho, and Stiroh, 2002).

21 To remind the reader, the tables should be read in the following manner. The gross output column shows the growth rates, the five columns of input contributions indicate the growth rates multiplied by the share weights, and the MFP column provides growth rates.

22 Output for a group is aggregated over industry outputs of the group using a translog index. Inputs are aggregated in the same fashion.

23 The bottom-up approach refers to aggregating from the industry level. This is in contrast with the top-down approach that refers to aggregation directly over commodity level with no industry dimension. Statistics Canada produces estimates using both approaches.

24 The aggregate MFP estimate of 1.1 in the second half of the 1990s for Canada was the same as the official estimate (Table 383-0001 in CANSIM). The estimate of 0.8 for the United States is similar to the estimate of *private sector* in Jorgenson, Ho, and Stiroh (2002) although that has a larger coverage. It is lower than the official estimate

of 1.3 from the U.S. Bureau of Labor Statistics (BLS News Release, April 8, 2003). The BLS measure of output and capital and labour inputs is different from ours (for the BLS method, see http://www.bls.gov/news.release/prod3.tn.htm). However, as noted in the section entitled *Data and Measurement Issues*, the relative MFP growth rates in the two countries should not be used as scoreboards, given several differences in the way changes in capital services are measured in the two countries. The measures here however are useful for examining whether changes in trends are common to the two countries.

25 It is interesting to note that IT-producing and IT-using industries maintain on average larger Domar weights in the United States than in Canada, which indicates that these industries in the United States are more intermediate input intensive than in Canada. However, in Canada, non-IT industries are generally more intensive in intermediate input than in the United States.

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Bibliography

Bureau of Economic Analysis (BEA). "Computer Prices in the National Income and Product Accounts." U.S. Department of Commerce, Bureau of Economic Analysis (National Income and Wealth Division, Investment Branch), 2001a.

——. "National Income and Product Accounts: Second Quarter 2001 GDP (advance) and Revised Estimates for 1998 Through First Quarter 2001." U.S. Department of Commerce, July 27, 2001b.

Bureau of Labor Statistics. News Release. Washington (D.C.): U.S. Department of Labor, April 8, 2003.

Christensen, L.R., and D.W. Jorgenson. "The Measurement of U.S. Real Capital Input, 1929-67." *Review of Income and Wealth* 4 (1969): 293-320.

Crawford, A. "Trends in Productivity Growth in Canada." *Bank of Canada Review* (Spring 2002): 19-32.

Domar, E.. "On the Measurement of Technological Change." *Economic Journal* 71 (1961): 709-729.

Doms, M., and C. Forman. "Prices for Local Area Network Equipment." Board of Governors of the Federal Reserve and Kellogg Graduate School of Management. Northwestern University, 2001. Manuscript.

Eldridge, L.P., and M.K. Sherwood. "A Perspective on the U.S.-Canada Manufacturing Productivity Gap." *Monthly Labor Review* 124 (February 2001): 31-48.

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

Gellatly, G., M. Tanguay, and B. Yan. "An Alternative Methodology for Estimating Economic Depreciation: New Results Using a Survival Model." In *Productivity Growth in Canada – 2002*. Edited by J.R. Baldwin and T.M. Harchaoui. Ottawa: Statistics Canada Catalogue No. 15-204-XPE, 2003.

Gu, W., and M.S. Ho. "A Comparison of Industrial Productivity Growth in Canada and the United States." *American Economic Review* 90, 2 (May 2000): 172-175.

Gu, W., and J.-P. Maynard. "The Changing Composition of the Canadian Workforce, 1961-95." In *Industry-Level Productivity and International Competitiveness Between Canada and the United States*. Edited by Dale W. Jorgenson and Frank C. Lee. Ottawa: Industry Canada, 2001. Research Monograph.

Gu, W., and W. Wang. "Information Technology and Productivity Growth: Evidence from Canadian Industries." In *Economic Growth in Canada and the United States in the Information Age*. Edited by Dale W. Jorgenson, 2004. Research Monograph, (Chapter 3 in this volume.)

Gu, W., M. Kaci, J.-P. Maynard, and M. Sillamaa. "The Changing Composition of the Canadian Workforce and its Impact on Productivity Growth." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin, and T.M. Harchaoui, Statistics Canada Catalogue No. 15-204-XPE, 2003.

Harchaoui, T.M., and F.Tarkhani. "A Comprehensive Revision of the Capital Input Methodology for Statistics Canada Multifactor Productivity." In *Productivity Growth in Canada - 2002*. Edited by J.R. Baldwin and T.M. Harchaoui, Statistics Canada Catalogue No. 15-204-XPE, 2003.

Harchaoui, T.M., F. Tarkhani, and B. Khanam. "Information Technology and Economic Growth in the Canadian and U.S. Private Economies." In *Economic Growth in Canada and the United States in the Information Age*, 2004. Research Monograph, Chapter 2 in this volume.

Harchaoui, T.M., F. Tarkhani, C. Jackson, and P. Armstrong. "Information Technology and Economic Growth in Canada and the U.S." *Monthly Labor Review* 125, 3 (October 2002).

Jackson, C. "Capitalization of Software in the National Accounts." *National Accounts*, Statistics Canada, 2001.

Jorgenson, D.W., and Z. Griliches. "The Explanation of Productivity Change." In *Postwar U.S. Economic Growth*. Edited by Dale W. Jorgenson. MIT Press, 1995, pp. 51-98.

Jorgenson, D.W., and F.C. Lee, eds. *Industry-level Productivity and International Competitiveness Between Canada and the United States*. Ottawa: Industry Canada, 2001. Research Monograph.

Jorgenson, D.W., F. Gollop, and B. Fraumeni. *Productivity and U.S. Economic Growth*. MIT Press, 1987, pp. 1-23.

Jorgenson, D.W., and K. Stiroh. "Raising the Speed Limit: U.S. Economic Growth in the Information Age." *Brookings Papers on Economic Activity* 1, 2000, pp. 125-235.

Jorgenson, D.W., and K.-Y. Yun. *Lifting the Burden: Tax Reform, the Cost of Capital, and U.S. Economic Growth*. MIT Press, 2001.

Jorgenson, D.W., M.S. Ho, and K.J. Stiroh. "U.S. High-Tech Investment and the Pervasive Slowdown in the Growth of Capital Services." 1999. Manuscript.

——. "Growth of U.S. Industries and Investments in Information Technology and Higher Education." Harvard University, 2002. Research Paper.

Lee, F.C., and J. Tang. "Productivity Levels and International Competitiveness Between Canadian and U.S. Industries." *American Economic Review* 90, 2 (May 2000): 176-179.

McKinsey Global Institute. *U.S. Productivity Growth 1995-2000: Understanding the Contribution of Information Technology Relative to Other Factors*. Washington (D.C.), October 2001.

Oliner, S.D., and D.E. Sichel. "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic Perspectives* 14, 4 (Fall 2000): 3-22.

Rao, S., A. Sharpe, and J. Tang. "Productivity Growth in Service Industries: A Canadian Success Story?" Paper presented at the Industry Canada Conference on Service Industries and the Knowledge-based Economy, Winnipeg, Manitoba, October 16-18, 2003.

Rao, S., and J. Tang. "The Contribution of ICTs to Productivity Growth in Canada and the United States in the 1990s." *International Productivity Monitor* 3 (Fall 2001): 3-18.

Rao, S., J. Tang, and W. Wang. “The Importance of Skills for Innovation and Productivity.” *International Productivity Monitor* 4 (Spring 2002): 15-26.

Robidoux, B., and B.-S. Wong. “Has Trend Productivity Growth Increased in Canada?” *International Productivity Monitor* 6 (Spring 2003): 47-55.

Stiroh, K.J. “Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?” *American Economic Review* 92, 5 (December 2002): 1559-1576.

Triplett, J. *Handbook on Quality Adjustment of Price Indexes For Information and Communication Technology Products*. Paris: OECD, 2001. DSTI/EAS/IND/SWP(2001)12.

Van Ark, B., R. Inklaar, and R.H. McGuckin. “More European than American? ICT and Productivity Growth at the Industry Level in Canada versus Europe and the U.S.” *International Productivity Monitor* 6 (Spring 2003): 56-63.

Appendix A

Measuring Capital Input and Labour Input

THE CONSTRUCTION OF CAPITAL INPUT AND LABOUR INPUT is more complicated than that for gross output and intermediate inputs. Some explanation is necessary to better understand the results emerging from the present study. We first discuss capital input.

Capital Input

Using investment data, capital stock for type *j* asset in industry *i* is constructed by the use of the perpetual inventory method,

$$\text{(A1)} \qquad Z_{i,j,t} - Z_{i,j,t-1} = I_{i,j,t} - \delta_j Z_{i,j,t-1}$$

where $Z_{i,j,t}$ and $I_{i,j,t}$ are capital stock and new investment of asset type *j* in industry *i* in year *t*. δ_j is the depreciation rate of asset type *j*, reflecting the rate of decline in the efficiency of the capital stock. It is assumed that the depreciation rate of an asset is constant over time and identical for all industries.

Capital stocks of different assets are then aggregated into capital input, which accounts for difference in quality or marginal productivity of those assets. To study the relative importance of IT capital and non-IT capital, this paper divides assets into two groups. The IT group includes computer hardware, software, and communication equipment, while the non-IT group includes other machinery and equipment, structures, inventories, and land.

To quantify the impact of substitution among different types of capital input under the current framework, capital input or service for each asset type is assumed to be proportional to the capital stock, that is, capital service for each asset is the same at all points of time. Under this assumption, the quantity index of IT capital input is defined as a translog aggregate of the different types of IT capital stocks

$$\text{(A2)} \qquad \Delta \ln K_i^{IT} = \sum_{m \in IT} \overline{v}_{IT,i,m} \Delta \ln Z_{i,m} \, .$$

where $\overline{v}_{IT,i,m}$ is the two-period average capital income share of type m IT asset in total IT capital income, and $\sum_{m \in IT} \overline{v}_{IT,i,m} = 1$.

Similarly, the quantity index of non-IT capital input is defined as a translog aggregate of the different types of non-IT capital stocks

(A3) $$\Delta \ln K_i^{NIT} = \sum_{m \in NIT} \overline{v}_{NIT,i,m} \Delta \ln Z_{i,m} .$$

where $\overline{v}_{NIT,i,m}$ is the two-period average capital income share of type m non-IT asset in total non-IT capital income, and $\sum_{m \in NIT} \overline{v}_{NIT,i,m} = 1$.

The capital income for each asset is estimated by multiplying its rental price by its capital stock. The rental prices are estimated based on the widely used capital user cost formula, originally developed by Christensen and Jorgenson (1969), and recently used by Jorgenson and Stiroh (2000) and Jorgenson and Yun (2001). The user cost for a specific asset in each industry accounts for investment tax credits, capital consumption allowances, the statutory tax rate, property taxes, debt/equity financing, and personal taxes. It is estimated by assuming that the ex-post actual rate of return on each asset is equal across all assets in each industry. For details of the tax parameters and estimation, see Jorgenson and Yun, and Jorgenson, Ho and Stiroh (2002) for the United States, and Harchaoui and Tarkhani (2003) for Canada.

Labour Input

The methodology for estimating labour inputs used in the present study was introduced by Jorgenson and Griliches (1995), and has been widely used in the study of sources of economic or productivity growth.

To capture the impact of labour with different education on labour productivity growth in the present study, the total labour input is divided into university labour and non-university labour inputs. To quantify the impact of substitution among different types of labour input under the current framework, labour input or service for each type is assumed to be proportional to the hours worked, that is, labour service for each type is the same at all points of time. Under this assumption, labour inputs are estimated on the basis of hours worked and labour compensation for each type of worker. The quantity index of university labour input is defined as a translog aggregate of the different types of hours worked

$$\text{(A4)} \qquad \Delta \ln L_i^{BA} = \sum_{m \in BA} \overline{v}_{BA,i,m} \Delta \ln H_{i,m} \,.$$

where $\overline{v}_{BA,i,m}$ is the two-period average labour compensation share of type m hours worked with university degree in total labour compensation for all hours worked by workers with university education, and $\sum_{m \in BA} \overline{v}_{BA,i,m} = 1$.

Similarly, the quantity index of non-university labour input is defined as a translog aggregate of the different types of non-university hours worked

$$\text{(A5)} \qquad \Delta \ln L_i^{NBA} = \sum_{m \in NBA} \overline{v}_{NBA,i,m} \Delta \ln H_{i,m} \,.$$

where $\overline{v}_{NBA,i,m}$ is the two-period average labour compensation share of type m non-university hours worked in total labour compensation for all hours worked by workers without university education, and $\sum_{m \in NBA} \overline{v}_{NBA,i,m} = 1$.

Appendix B

Current Practices in Estimating IT Price Indexes in Canada and the United States

MANY PEOPLE HAVE QUESTIONED PRODUCTIVITY NUMBERS related to information technologies. In particular, their perception is that U.S. IT data incorporates more drastic decline in IT prices than the corresponding Canadian data. Consequently, Canada will show relatively lower output and productivity growth in IT-producing industries and higher output and productivity growth in IT-using services. Therefore, it is important to document the methodology used in Canada and the United States. In this appendix, we describe the methodologies used by statistical agencies in Canada and the United States in estimating the prices for computers, telecommunication equipment, and software. We show that the methods used by Canada and the United States for developing the IT price indexes are fairly similar.

The database developed by Jorgenson and his research team for productivity analysis is mainly based on data from the U.S. Bureau of Economic Analysis (BEA). Thus, our discussion for the United States will be centered on the methodologies used by the BEA. Table B1 summarizes techniques used in estimating the prices of IT products in the two countries.

Table B1

Methods of Estimating IT Price Indexes in Canada and the United States

IT Products	Countries	Methods
Computers	United States	Mixed hedonic regression and match model; Fisher chained
	Canada	Mixed hedonic regression and match model; Fisher chained
Communication Equipment	United States	Mixed hedonic regression and match model; Fisher chained
	Canada	Match model technique; Fisher chained
Software	United States	Mixed hedonic regression and match model; Fisher chained
	Canada	BEA methodology; Fisher chained

Computers

United States

Computers and peripheral equipment include mainframes, PC's, storage devices, displays, and peripheral equipment, and others. BEA's computer price indexes reflect four types of detailed quality adjusted computer price indexes: 1) the BEA composite price index, 2) the BEA chained match-model price index, 3) the BEA regression price index, and 4) the BLS price index (BEA, 2001a).

- The BEA composite price indexes are used for most components of the computers and peripheral equipment price index for the period 1972-92. The composite index uses both observed prices and prices imputed from a regression equation to construct a price index. The composite price index combines the strengths of the match-model and hedonic methods. The regression equation or hedonic function, is used to estimate prices of characteristics (speed, memory, etc.).

- The BEA chained match-model price indexes are used for constructing the price indexes for PC's in select time periods, beginning with 1982.

- The BEA regression price index is used for estimating the price index for tape drives for the period of 1972-83. The regression index is formed from the coefficients for the year dummies in a hedonic function that relates prices paid for tape drives to quality characteristics such as speed and memory size.

- BLS price indexes, including producer price indexes (PPI), international price indexes (IPI), and consumer price indexes (CPI) are generally reflected in the NIPA computers and peripheral equipment price indexes as they become available. For components of the NIPA computers and peripheral equipment price index that are estimated from multiple PPI's, the Fisher chain-type formula is used to combine the more detailed PPI's. Other components are estimated directly from the BLS PPI or IPI.

Canada[1]

- The Canadian price index incorporates some prices from the U.S. series, as well as some from Canada. From 1981 onward, Canada has used a weighted average of the BEA series for computers, direct access storage drives, printers, and displays, using weights based on Canadian production levels.

- The BEA tape drive index was not used because the output of this product is small in Canada.

- The BEA series were incorporated into the Canadian price index through 1992, at which point, price indexes for microcomputers and printers were based on prices collected in Canada and adjusted with a hedonic procedure. The BEA series were adjusted for exchange rate variations in order to express the indexes in terms of Canadian prices.

Telecommunication Equipment

United States

Telecommunication equipment includes LAN equipment such as routers, switches, LAN cards, hubs, and others.

The BEA price index for telecommunication equipment is based on the estimate from the Federal Reserve Board (FRB) (BEA, 2001b). The FRB estimate is based on a mixed hedonic regression and match model techniques (Doms and Forman, 2001). Hedonic regressions were used to estimate price changes for the two largest classes of LAN equipment, routers and switches. A match model was used for LAN cards and the prices for hubs were inferred by using an economic relationship to switches.

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[1] For details, see Eldridge and Sherwood (2001).

Canada

Telephone Switching Equipment

Canada produces a price series for telephone switching equipment based upon purchased prices collected from Canadian telephone companies. The match model is used.

Semiconductors

Canada does not collect prices for semiconductors, but rather uses BLS price indexes for several products within the semiconductor industry to proxy deflators for integrated circuits and semiconductors and parts. The BLS producer price indexes for semiconductors are constructed using a match model technique. The producer price indexes are adjusted by Statistics Canada for exchange rate variations.

Software

Software is further disaggregated into three asset types: pre-packed, custom-design and owner-account. The price indexes are different for different software.

United States

The BEA price index for pre-packaged software has several parts: the BEA price index for computers and peripherals in private fixed investment (1981-84); an average of the BEA hedonic price index and a match-model price index for spreadsheets and word-processors (1985-93); the BEA match-model price index (bias-corrected) for selected pre-packaged software (1994-97); and the U.S. Bureau of Labor Statistics (BLS) producer price index (bias corrected) for pre-packaged application software (1988 onwards).

Canada

The Canadian price index for pre-packaged software is an adjusted BEA price index (Jackson, 2001). The adjusted BEA price index is an average of the BEA price index, weighted by the domestic share of supply to the domestic market, and an exchange-rate adjusted BEA price index, weighted by the import share of supply to the domestic market. For the exchange-rate adjusted BEA price index, it is assumed that exchange rate fluctuations are fully passed through to the domestic price of imported software.

The BEA price index for own-account software is a reflection of increase in the median price of a business employee in the U.S. economy, including the cost of salary, and all additional compensations and overhead (McKinsey Global Institute, 2001).[2]

The Canadian price index for own-account software is also estimated based on the wage bill for computer programmers and system analysts. It is a fixed-weighted average of an index of the average hourly earnings for programmers and system analysts and an index of the costs of non-labour inputs to the computer services industry. The weights are fixed to about two-thirds and one-third, respectively.

For both the BEA and Canada, the price index for custom-design software is derived as a weighted average of the changes in the price indexes for pre-packaged software and own-account software. The weights are fixed to one quarter and three quarters, respectively.

IT Price Indexes in Canada and the United States

In this section, we present the price indexes of IT products used by Statistics Canada and the BEA. It should be noted that the price difference between the two countries reflects not only the difference in methods but also the difference in the product mix.

Table B2 shows annual changes in the prices of computers, telecommunication equipment, and software in Canada and the United States. These prices are implicit price deflators for business investment in these IT equipment and software.

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2 Implicitly, it assumes that there is no productivity gain for persons who engage in the software development.

Table B2

Average Annual Change in IT Prices in Canada and the United States (Percent)

	Computers		Communication Equipment		Software	
	Canada	**United States**	**Canada**	**United States**	**Canada**	**United States**
1981-88	–17.70	–13.38	3.91	2.67	–1.23	0.88
1988-95	–14.58	–12.15	–2.45	–0.39	–4.58	–1.54
1995-2000	–18.29	–25.23	–1.39	–2.96	–1.12	–0.86
1981-2000	–16.71	–16.04	0.17	0.06	–2.44	–0.47

For the 1981-2000 period, the prices of computers and telecommunication equipment show similar changes in Canada and the United States while the price of software shows faster decline in Canada than in the United States. For both countries, the prices of computers declined at about 16 percent per year over the 1981-2000 period and the price of telecommunication equipment was virtually unchanged. For software, the price declined at an annual rate of 2.4 percent in Canada, compared to 0.5 percent in the United States. However, the price decline for computers in Canada was slower than in the United States in the second half of the 1990s. The difference was partly due to the depreciation of the Canadian dollar relative to the U.S. dollar.

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