OECD Economic Studies No. 40, 2005/1

WHATEVER HAPPENED TO CANADA-US ECONOMIC GROWTH AND PRODUCTIVITY PERFORMANCE IN THE INFORMATION AGE?

Tarek M. Harchaoui and Faouzi Tarkhani

TABLE OF CONTENTS

Both authors work in the Micro-Economic analysis Division of Statistics Canada. An earlier version of this paper was presented at the International Association of Official Statistics Meeting in London, UK, August 2002, and at the Ottawa Productivity Workshop, November 2002. The comments and suggestions made by B.K. Atrostic, John Baldwin, Erwin Diewert, Mike Harper, Steven Landefeld and the participants at those meetings are acknowledged with thanks. We also thank Dirk Pilat and Hannes Suppanz for their comments on a recent version of the paper. The views expressed in this paper are those of the authors and do not reflect in any way Statistics Canada's point of view. This study used the September 2002 vintage of the Canada-US data which have been subsequently revised. Despite significant revisions for GDP growth (upward for Canada and downward for the United States), the story laid out in this paper remains unchanged.

INTRODUCTION

Some of the recent "hype" about how advances in technology are forging a "new economy" has evaporated. Interest in "dot.com" start-up companies in the US has waned with the decline in stock market valuations. Some of the more extravagant claims – in particular, that the "new economy" would see the end to recessions – have been tempered by the recent slowdown in the US economy.

But a central, underlying issue – whether information technology raises a country's productivity performance over the long term – remains relevant. The US economy is viewed in many respects as a technology and productivity "leader". The new information technology-based source of productivity growth that has emerged in the US economy (putting aside the short-term cyclical downturn) raises the potential for countries such as Canada to follow suit.

The motivation for the present study is the striking increase in the growth of US labour productivity that occurred in the second half of the 1990s. This increase was accompanied by an investment boom in information technology equipment. There now seems to be general agreement that a large part of the increase in output can be accounted for by rapid growth in information technology equipment [see Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000 and Council of Economic Advisers (CEA) 2001]. The information technology investment boom in turn was driven by the rapid rate of decline of computer prices, which accelerated in the second half of the 1990s (see Tevlin and Whelan, 2000). The fall in computer prices has been mainly due to rapid technical progress in semi-conductors (see Jorgenson, 2001; Jorgenson and Stiroh, 2000; and Oliner and Sichel, 2000). In contrast, Gordon (2000) argued that the majority of the recent productivity acceleration is due to cyclical forces with the remainder concentrated in the relatively small portion of the economy engaged in the production of IT technology. More recent work in this area concurred that the US productivity revival was broad based (Bosworth and Triplett, 2004 and Jorgenson *et al.*, 2004a).

While the resurgence of US productivity growth that began in 1995 is by now well documented and widely understood, the strength of the post-2000 productivity performance remains ill understood. The recent attempts that investigated the sustainability of the US productivity performance after the 2001 recession include Jorgenson *et al.* (2004b), Gordon (2004), CEA (2003) and Oliner and Sichel (2002). For example, the ebullient productivity performance of the post-2000 period has led Gordon (2004) to ask why productivity growth accelerated after 2000 when the information technology investment boom was collapsing. In their recent outlook of the US productivity revival, Jorgenson *et al.* (2004b) concluded that when the 2001 recession and recovery are included, the data show that the acceleration of labour productivity can be largely attributed to more rapid capital deepening and faster non-information technology multifactor productivity growth. In their 2003 Economic report of the President, CEA (2003) showed that multifactor productivity acceleration from 1973-1995 to 1995-2002 was even more robust that the one reported in their 2001 report for the periods 1990-1995 to 1995-2000 (1.21 percentage point compared with 1.19).

However, there are differing views outside the US on the links between information technology and productivity performance. A recent OECD study (OECD, 2001) reached the conclusion that "ICT (*information and communication technology*) *is important for growth but having an* ICT-*production sector is not a prerequisite*". Australia, which enjoyed a remarkable improvement of productivity largely due to information technology use, is an interesting case in point (Parham, 2002).

What is the story for Canada – a country with economic structures similar to those of Australia? Using revised Canadian data that accord with the best practice in the area of productivity measurement, Harchaoui *et al.* (2002) stressed that the mechanisms underlying the structural transformation of the Canadian business sector are already at work. As an illustration, consider the role that information technology plays as a source of economic growth. For the 1981-1988, information technology capital input contributed 12% to Canadian economic growth. During this period, information technology prices have continuously fallen and businesses substituted towards relatively cheaper inputs. During the late 1990s, following a major slowdown in the Canadian economy in the early 1990s, information technology prices continued to fall, reaching 3.2% per year on average. In response, investment in information technology has exploded but the growth contribution of information technology capital input increased moderately, reaching 14% on average between 1995 and 2000.

Next, consider the productivity performance that accompanied the remarkable 4.9% economic growth in the late 1990s. Labour productivity grew 1.7% per year during 1995-2000, almost half of a percentage point faster than during 1981-1988. A detailed decomposition shows that capital deepening – the direct consequence of price-induced substitution and rapid investment – contributed 0.4 percentage point, up from 0.3 percentage point during the 1980s. Labour composition added 0.3 percentage point, compared with 0.5 in the 1980s, a reflection of the exhaustion of the pool of available workers. Faster multifactor productivity contributed an additional 1 percentage point, an unprecedented performance since 1981.

It turns out that information technology had played a lesser role in the Canadian productivity performance than that of the United States. Unfortunately, the empirical record reported in our earlier work remains incomplete and so much remains to be done before definitive assessments can be made about the complete role of information technology. Clearly, there are some important issues to be examined for Canada and sorted out irrespective of the "new economy hype".

This paper addresses these issues. It takes a wider view than our recent study since it quantifies, within a unified framework, the contributions of each of the information technology components (computers, software and telecommunication equipment) to output, capital services and labour productivity growth. It also provides an empirical record on the sectoral (*i.e.* information technology-producing vs. information technology-using industries) sources of the Canadian productivity revival and the extent to which these gains are linked to information technology use. Comparisons with the US are also examined using the most comparable data available and the evidence on the sectoral sources of the US productivity surge is also revisited.

This paper reaches several conclusions, some of which were untapped by the existing economic literature.

First, the paper concludes that information technology has contributed modestly to the Canadian growth resurgence and productivity gains, compared with the US where it played a central role. This result holds even when we control for the methodological differences in the measurement of information technology prices at the industry level.

Second, this paper also traces the sources of the modest contribution of information technology in Canada at the aggregate level. Information technology output and information technology capital input grew virtually at the same pace in both Canada and the United States. In contrast, Canada's information technology share of the value of output and capital cost is about half of those of the US, a reflection of major difference in the structures of the two economies.

Third, the difference between Canada and the US performance is attributable to differences in the sectoral sources of productivity gains. Virtually all of the recent Canadian productivity gains are ascribed to information technology-using industries, a sharp contrast with the US where information technology-producing industries contributed to the bulk of the aggregate productivity gains. Contrary to the common US wisdom, this finding therefore leaves very little room for multifactor productivity gains from other industries.

Fourth, despite the collapse of information technology capital formation, the recent data show that the rapid multifactor productivity performance surge that emerged in 1995 remained persistent in the early years of this new century. The recent update of the productivity estimates through 2003 indicates that multifactor productivity growth in both Canada and United States during the 2000-2003 period remained as strong as that of the late 1990s.

The remainder of the paper is organised as follows. The next section reviews the US productivity literature, including the most recent contributions. It then introduces the measurement framework and discusses the data sources that are adequate for a meaningful Canada-US comparison. This section examines, in particular, the delineation of information technology industries and measurement of information technology prices, two data issues that are critical for an accurate account of the role of information technology. The penultimate section provides a comprehensive comparison between Canada and the US in terms of the various channels through which information technology operates. It provides evidence in two different, albeit complementary, directions: first, it quantifies the differences in the contributions of information technology in the two countries. Second, it ascertains the impact of methodological differences in the prices between the two countries on the productivity performance of the Canadian information technology-producing industries and, along the way, on the sectoral allocation of aggregate productivity growth. The final section summarises the findings and suggests some directions for future research.

INFORMATION TECHNOLOGY IN CANADA AND US: WHAT IS THE STORY?

Preliminary remarks

The acceleration in US productivity growth in the second half of the 1990s has attracted much attention. There has also been particular interest in the role that information technology played in sustaining the strong US performance. The US productivity acceleration coincided with an acceleration in advances in information technology, investment in information technology equipment and the take-off in the wider use of the Internet.

The role of information technology in promoting productivity and output growth is of considerable interest to Canada as well. As a productivity leader, the US economy does not catch up – it is at the forefront. The US economy essentially relies on technology breakthroughs to step up its rate of productivity growth. If a new way to increase productivity growth is found in the US, it raises the prospects for other countries like Canada to follow and ride on a new productivity wave.

The US studies have analysed the labour productivity acceleration in the second half of the 1990s – that is, before and after 1995, the point of take-off in advances in technology, declines in information technology prices, growth in investment in information technology and growth in labour productivity. Gordon (2000, 2004), Oliner and Sichel (2000, 2002), Jorgenson and Stiroh (2000, 2004b), the BLS in its own published work and the CEA (2001, 2003) all compared periods up to and including 1995 with the period from 1995 on.These studies are briefly reviewed below.

A *brief review of the* US *evidence*

Three studies have been particularly influential in the analysis of the role of information technology in the US acceleration in output and productivity growth – Oliner and Sichel (2000, 2002), Jorgenson and Stiroh (2000) and the more sceptical view of Gordon (2000).[1]

Oliner and Sichel (2000, 2002) and Jorgenson and Stiroh (2000) consider three related factors to be prominent in the relationship between information technology and US growth and productivity performance:

1. There have been rapid advances in multifactor productivity in the production of information technology – especially through the production of more powerful semiconductors, with little or no more input requirements.
2. These productivity advances have enabled relative and absolute price declines for information technology equipment – prices have declined by 18% a year from 1960 to 1995 and by 27.6% a year from 1995.
3. Lower prices have helped to stimulate very strong demand for information technology, especially in the second half of the 1990s.

These factors imply aggregate labour productivity gains via multifactor productivity gains in computer production and capital deepening in using industries as firms raise the ratio of information technology capital services to labour.

Oliner and Sichel (2000) conducted what has become a central study. They found that information technology contributed about 0.7 of a percentage point (or about two-thirds) of the 1 percentage point acceleration in US labour productivity growth between the first and second halves of the 1990s (specifically, between 1991-1995 and 1996-1999). This comprised 0.42 of a percentage point from information technology capital deepening and 0.26 of a percentage point from multifactor productivity growth in information technology production. Capital deepening from other forms of capital contributed almost nothing to the acceleration, leaving multifactor productivity growth in industries outside of information technology production to account for the rest (see Table 1).

Despite the results that show the highest multi-factor productivity acceleration in information technology using industries, Jorgenson and Stiroh (2000) were unconvinced about the importance of multifactor productivity gains associated with information technology in the non-information technology producing-sector as the majority of its constituent industries continue to experience productivity measurement problems. Gordon (2000) has been the most prominent sceptic. He removed what he considered to be a transient cyclical component from the

Table 1. **Estimates of contributions to the US multifactor productivity acceleration in the 1990s**

	Gordon (2000)	Jorgenson and Stiroh (2000)	Jorgenson, Ho and Stiroh (2004b)	Oliner and Sichel		CEA	
				(2000)	(2002)	(2001)	(2003)
Multi-factor productivity acceleration	0.29	0.63	0.80	0.68	0.62	1.19	1.21
Information technology-producing industries	0.29	0.18	0.28	0.26	0.26	0.18	0.13
Information technology-using industries	0.00	0.44	0.51	0.42	0.36	1.00	1.08

aggregate labour productivity acceleration and made a further correction for mismeasurement. The remaining structural acceleration in labour productivity growth of 0.8 of a percentage point, less the contribution from capital deepening, virtually equalled his estimate of the multi-factor productivity gains from computer production. This left virtually no room for any multi-factor productivity gains from any other industries (see Table 1).

The widespread reporting of Gordon's conclusion has undoubtedly contributed to a fairly common view that production of information technology is the only way to access "new economy" productivity gains (even though Gordon accepted that information technology use did contribute to labour productivity growth through capital deepening). However, the evidence of multifactor productivity gains in industries outside of information technology production found in other studies is hard to "explain away".

Additional studies reveal stronger multifactor productivity acceleration in the US economy (up to the year 2000). An update from Oliner and Sichel (2002) and the CEA (2001) found a stronger labour productivity acceleration to the year 2000, most of which is attributed to stronger multifactor productivity acceleration. Around three-quarters of the multifactor productivity acceleration was attributed to non-information technology-producing industries (see Table 1).

More detailed industry studies are now showing evidence of productivity acceleration in information technology-using industries. Nordhaus (2001) found that industries outside of broadly-defined "new economy" production contributed about a half of the aggregate labour productivity acceleration. Stiroh (2001) found that (a narrower group of) information technology production industries contributed about one-fifth of the aggregate acceleration and information technology-using industries contributed nearly all of the remainder, with little acceleration in industries outside of information technology production or use. More recent US studies tend to suggest that the US productivity acceleration was broad based. Bosworth and Triplett (2004) focus on the performance of service industries and find a widespread acceleration. Jorgenson *et al.* (2004a) also find that multifactor productivity accelerated outside information technology production, although by a smaller amount.

Other recent studies have examined the post 2000 productivity outlook. In their 2003 report, CEA (2003) showed that, using data through 2002, the multifactor productivity revival appears more robust than initially reported in 2001 (CEA, 2001) and most of it is ascribed to information technology-using industries. The data that emerged in 2000-2003 have led Gordon (2004) to adopt a more optimistic view of the productivity revival than the one he adopted in his earlier work (Gordon, 2000). The data through 2003 suggest that little of the late 1990s upsurge was cyclical. In an update to their previous work, Jorgenson *et al.* (2004b) have identified several changes in the makeup of the productivity revival. When the 2000-2003 period is considered in the decomposition of the productivity revival (1995-2000 less 1973-95 *vs.* 1995-2003 less 1973-95), labour productivity now shows a larger increase. The change in the acceleration of labour productivity is largely attributed to more rapid capital deepening and faster non-IT multifactor productivity growth. Both information technology and non-information technology capital are now larger. The increase in capital deepening occurred because the growth of hours slowed more than the growth in non-information technology capital services, resulting in an increase in non-information technology capital per hour worked. The contribution of labour quality to the post-1995 revival is essentially unchanged. Finally, the contribution of multifactor productivity associated with information technology production has not changed, while we now see a much larger contribution from non-information technology multifactor productivity growth.[2]

Whilst this evidence of productivity acceleration in using industries does not establish conclusive proof of information technology-related effects, since non-information technology factors could still be at work in information technology-intensive industries, it strongly suggests that information technology use has contributed to productivity acceleration in information technology-intensive industries. This conclusion is also supported by the findings from a major OECD study of factors contributing to differences in growth rates across economies in the 1990s (OECD, 2001). It found that productivity gains came from information technology use, as well as production.

Framework and data sources

A critical first step in understanding the economic impact of information technology is to successfully quantify information technology in a way that is consistent with both economic theory and the available data. The appropriate theory is a production framework that relates real GDP to various production inputs and the level of technology. This framework has two important features: *a*) it quantifies, at the aggregate level, the various channels through which information technology operates, that is, output and inputs; and *b*) it traces the sectoral sources of the aggregate productivity growth.

Measurement of output

The framework employed here is based on the production possibility frontier recently used by Jorgenson and Stiroh (2000). This framework captures substitutions among outputs of investment, consumption, exports and imports, as well inputs of capital and labour. We identify information technology-GDP with investment, personal expenditures and net exports in computers, software, and communications equipment and non information technology as the residual component of GDP. The service flows of the investment assets are also inputs.

The aggregate production possibility frontier can be rewritten in an extended form to highlight the role of information technology

$$Y\left[Y_{IT}(t), Y_{NIT}(t)\right] = A(t) \cdot f\left[K_{IT}(t), K_{OME}(t), K_S(t), L(t)\right] \quad [1]$$

where Y_{IT} and Y_{NIT} are, respectively, real information technology and non-information technology outputs; K_k is capital services generated by capital asset *k* [*k* = information technology (IT) other machinery and equipment (OME), and structures (S)], L is a measure of labour input that represents both the composition of the labour force and the number of hours worked and A is often referred to as multifactor productivity, and measures how effectively inputs are transformed into outputs. An increase in multifactor productivity indicates that more output is produced from the same inputs.

Under standard economic assumptions about capital, labour, and output markets, theory suggests that equation [1] can be transformed into a growth rate version where the weighted growth rates of various outputs equal the weighted growth rates of inputs plus the growth rate of multifactor productivity:

$$w_{Y_{IT}} \Delta \ln Y_{IT} + w_{Y_{NIT}} \Delta \ln Y_{NIT} = v_{K_{IT}} \Delta \ln K_{IT} + v_{K_{OME}} \Delta \ln K_{OME} + v_{K_S} \Delta \ln K_S + v_L \Delta \ln L + \Delta \ln A \quad [2]$$

where *w* refers to the nominal share of the subscripted output in nominal GDP, *v* refers to the nominal share of the subscripted input in nominal GDP, refers to a change or first difference in percentage, and the following equalities must hold

$$w_{Y_{IT}} + w_{Y_{NIT}} = v_{K_{IT}} + v_{K_{OME}} + v_{K_S} + v_L = 1.0$$

The share-weighted growth of each variable in [2)] is referred to as the "contribution" of that variable.

Equation [2] is a standard "growth accounting" equation that has several attractive features. First, it enables us to identify the contribution of information technology to the growth of output and capital input. Second, it decomposes the sources of economic growth in terms of the different types of capital inputs – information technology, other machinery and equipment and structure – labour input and multifactor productivity growth, a residual defined to balance equation [2].

The source of information used to implement the production possibility frontier is the income and expenditures accounts and the national income and product accounts ("national accounts") produced, respectively, by Statistics Canada and the US Bureau of Economic Analysis. The national accounts measure of the business sector's GDP is based on deflated expenditures on "final" goods and services. Expenditures on intermediate inputs of materials and services are excluded. Computers, communications equipment, and software as investments made by businesses and governments, along with net exports to the rest of the world, are part of GDP. GDP also includes the expenditures of information technology products made by households, but not the services flows of information technology consumers' durables.[3] While semiconductors form an important part of the information technology revolution, only their net exports defined as the difference between exports to the rest of the world and imports appear in the GDP.

We now turn our attention to industry framework to trace the sectoral sources of the aggregate multifactor productivity growth. The approach utilises the internal consistency between the business sector GDP series and the measure of output of its constituent industries. The first component consists of a production function for each industry and the second is the Domar (1961) methodology for aggregating over industries to obtain an aggregate measure of productivity. Recent contributions that applied this methodology to quantify the contribution of information technology-producing industries to the aggregate multifactor productivity revival includes Jorgenson and Stiroh (2000), Jorgenson *et al.* (2004a) for the US, and Harchaoui *et al.* (2004a) for a Canada-US comparison.

Industry income and product accounts of both countries produce a variety of industry measures of output, all of which reflect in different ways the deliveries to final demand and the inter- and intra-sectoral transactions.[4]

Using KLEMS data based on gross output or gross product originating available at the two-digit 1987 Standard Industrial Classification (SIC) level from the US Bureau of Economic Analysis, several US studies have focused on SIC 35, industrial and commercial machinery and equipment and computer equipment, and SIC 36, electronic and other electrical equipment and components.[5] An alternate KLEMS dataset, based on the notion of sectoral output, available at the same level of industry detail, is also produced by the US Bureau of Labour Statistics. However, all of these data suffer from the disadvantage of mixing information technology producing industries with electrical products industries which are, by definition, remotely linked to the notion of information technology.[6]

There is, however, an additional, albeit less popular, source of information available from the US Bureau of Labor Statistics that provides more industry detail and, as a result, overcomes this problem of coverage of information technology-producing industries.[7] The multifactor productivity programme for three-digit SIC manufacturing industries produces a KLEMS database based on the notion of sectoral output from 1987 to 1999 for 102 manufacturing industries, including each of the information technology producing industries,[8] computer and office equipment (SIC 357), communication equipment (SIC 366), and electronic components and accessories (SIC 367). All in all, these industries produce each of the major information technology products, that is, computer hardware for SIC 357, communication equipment for SIC 366, and semiconductors and related products for SIC 367. Software may be produced by each of these industries.[9]

The Canadian productivity accounts construct a variety of productivity measures for 122 industries (1980 SIC-E) of the business sector based on a set of inter- and intra-industries transaction accounts available from Statistics Canada's input-output tables. Information technology-producing industries cover two of these 122 industries: electronic equipment industry (# 335) and office, store and business machine industry (# 336) which produce, respectively, telecommunications equipment, semiconductors, printed circuits and integrated circuits, and computer hardware. Much like the US, software products are produced by each of the Canadian information technology-producing industries. The lack of availability of capital prevents the Canadian productivity accounts from having a split between the communication part and the semiconductors and integrated circuits part of the industry # 336. Nonetheless, detailed information on outputs and intermediate inputs for these two parts is available from the Canadian input-output tables. This information is particularly useful to examine the structures of the information technology-producing industries in Canada (more on that below).

Given the variety of industry data sources available for the US, the issue is which one is more adequate for productivity measurement. In the context of the US statistical system, the notion of sectoral output produced by the US Bureau of Labor Statistics is consistent with the aggregate private business sector GDP (see Gullickson and Harper, 1999). This is not the case for the notion of gross product originating used in various United States productivity studies.[10] Gross product originating is based on the income side of national income accounts, an approach that makes the productivity revival larger as the estimated income grew more rapidly than the estimated product accounts (see Bailey, 2002; 7 and Bosworth and Triplett, 2004).

Given the consistency problem associated with the notion of gross product originating, we are left with two options to perform our Canada-US comparison:

either to use the notion of gross output produced by the US BEA or the notion of sectoral output. In this paper, we chose to use the notion of sectoral output and we leave the use of gross output for another Canada-US study (see Harchaoui *et al.*, 2004a).[11]

Table 2 illustrates the structures of the information technology-producing industries in both Canada and US and how they have evolved between 1988 and 1999.[12] For the US, the three information technology-producing industries accounted for 11.8% of the manufacturing sector's sectoral output in 1999, up from 8.4% in 1988. Within these industries, computer and office equipment saw its share decline from 40.2% down to 30.7% to the benefit of electronic components and accessories from 35.5% to 41.5% and, to a lesser extent, communication equipment from 24.3% to 27.7%.

Table 2. **Output structures of Canadian and US information technology-producing industries**

	Canada		United States	
	Millions of Canadian dollars		Millions of dollars	
	1988	1999	1988	1999
Communication equipment[1]	5 105	11 752	34 343	85 638
Share in information technology-producing industries	51.0%	47.7%	24.3%	27.7%
Electronic products and accessories	1 656	7 767	50 115	128 117
Share in information technology-producing industries	16.5%	31.5%	35.5%	41.5%
Computers and office equipment[2]	3 257	5 122	56 747	94 882
Share in information technology-producing industries	32.5%	20.8%	40.2%	30.7%
Information technology-producing industries	10 018	24 641	141 206	308 638
Share in total manufacturing	3.3%	5.1%	8.4%	11.8%
Total manufacturing	303 588	483 148	1 689 803	2 618 207

1. The Canadian communication equipment industry is composed of telecommunication equipment industries and other communication and electronic equipment industry. In 1999, the sectoral output share of these two industries was respectively 76% and 24%, compared with 51.3% and 48.7% in 1988.
2. The Canadian computers and office stores industry is composed of electronic computing and peripheral equipment industries and electronic and other office, store and business machines industries. In 1999, the sectoral output share of these two industries was respectively 98.8% and 1.2%, compared with 95.6% and 4.4% in 1988.

Although the output share of Canadian information technology-producing industries within the manufacturing sector increased from 3.3% to 5.1%, it represents only about 40% of its US counterpart. Similar to the US, the share of electronic components and accessories industry increased from 16.5% to 31.5% between 1988 and 1999, mostly at the expense of the computers and office stores industry which saw its share drop from 32.5% to 20.8%.

Despite this similar trend in the share of information technology-producing industries between Canada and US, the structures of the information technology-producing sector remain different between the two countries. The communication equipment industry accounts for almost half of the Canadian information technology-producing sector, compared with about one-quarter for its US counterpart. Canadian electronic products and accessories and computers and office stores industries, which account for the remaining half, have a lower share than their US counterparts. For example, in 1999 these two industries accounted, respectively, for 31.5% and 20.8%, compared with 41.5% and 30.7% in the United States.[13]

The issue of information technology prices

The construction of a consistent time series of constant price series on information technology requires the availability of "constant-quality price indexes". These prices effectively capture the quality improvements across successive generations of information technology products and treat these quality gains as a reduction in the price of information technology.

Given that the examination of the sources, concepts and method utilised in both Canada and US is beyond the scope of this paper, we proceeded as follows.[14] For each information technology product and industry, we examined the two countries' price behaviour over the 1981-2000 period for which we have consistent information. Where the price behaviour appeared substantially different, we attempted to identify the potential source of the difference and to explain the extent to which it will impact on the result using commodity as well as industry data to the extent that they are both available. Our examination, which is available on request, led to the following conclusions at both the aggregate and industry levels:

1. First, from the examination of the final demand information technology prices, we conclude that the overall trends of Canadian and US prices are for the most part similar. This is particularly the case for imports on one hand and computers that appear under the investment category, on the other hand. There are, however, some differences between the two countries in the prices of software and telecommunication assets in the investment category and information technology products that appear under personal expenditures. Canada's software prices decline more rapidly and *vice versa* for telecommunication and information technology personal expenditures. This reflects perhaps a combination of methodological differences in the structure of the economy and even the exchange rate. However, at the level at which we

have established the comparison between the two countries (information technology-GDP) these differences are likely to offset one another.

2. There are, however, several issues related to the implicit price indexes of sectoral output and information technology sectoral intermediate inputs that have some important bearing on Canada-US comparison of productivity trends for the three information-technology-producing industries.

   First, there seems to be a pass-through mechanism from the prices of information technology sectoral intermediate inputs to those of sectoral output in Canada. The implicit price indexes of sectoral output for each of the information technology-producing industries mirror those of their corresponding sectoral intermediate inputs, thereby reflecting the fact that technical change that occurs in upstream industries is transmitted to downstream industries.

   Second, there is a difference in the behaviour of the Canadian output implicit price index of electronic products and accessories, compared with its US counterpart. Canada does not collect prices for integrated circuits, printed circuits and semiconductors, but rather uses the Bureau of Labor Statistics producer price indexes for the corresponding products based on the matched model technique. These indexes are adjusted by Statistics Canada for exchange rate variations. Yet, the implicit price index of the output of electronic products and accessories for this industry fell by about 75% in the US, while only 25% in Canada. Differences in the weighting schemes and the fluctuations of the exchange rates may explain this difference.[15]

   Third, Canada's implicit price index of communication industry's output behaves differently from its US counterpart. Canada applies the matched model technique to telephone equipment based upon purchased prices collected from domestic companies. In contrast, the US employs quality-adjusted price indexes based on hedonic estimates only for telephone switching equipment; conventional price deflators are employed for transmission gear and other components.

   The largest information technology-producing industry in Canada – communication industry – is the one that reports a trend of the output price index that is different from its US counterpart. The productivity growth gap in information technology-producing industries in favour of the US is, therefore, largely attributable to this industry.

   Similarly, differences in the output price behaviour of the electronic components and accessories industry in favour of the US also contribute to this gap.

   Later, under the sub-section "Sectoral sources of Canada and US productivity revival", we will attempt to quantify how much of these differences in the output price indexes of these two industries contribute to the difference in productivity trends.

Measurement of Capital and Labour Inputs

Previously we have discussed the concept of output available for a Canada-US comparison and the issue of measurement of information technology prices. This section moves on to the input side and draws a comparison in terms of concepts and methods of capital and labour inputs.

The capital input for the multifactor productivity measures in both Canada and the US is computed in accordance with a service flow concept for physical capital assets. We employ a broad definition of capital, including tangible assets such as machinery and equipment, structures, as well as land and inventories.

The estimates of the services price of capital assets incorporate differences in asset prices, service lives and depreciation rates, and the tax treatment of capital incomes (see Harchaoui and Tarkhani, 2003 for a description of the methodology for Canada). Capital inputs for major sectors are determined in three main steps: 1) a detailed array of capital stocks is developed for various asset types in different industries; 2) asset-type capital stocks are aggregated for each industry to measure capital input for the industry; and 3) industry capital inputs are aggregated to measure sectoral level capital input.[16]

The Canadian asset detail consists of 16 types of machinery and equipment (28 for the US), six types of non-residential structures (22 for the US), four types of residential structures[17] (nine for the US), three types of inventories (by stage of processing), and land.

Statistics Canada's procedures are applied to 122 industries of the business sector (109 manufacturing industries for the US) in the business sector corresponding, approximately, to the two and three-digit 1980 SIC level (three-digit 1987 SIC for the United States). These measures of capital stocks are aggregated using a Fisher (Törnqvist for the US) chain index procedure. The weight for each asset type is based on the share of property income estimated to be accruing to that asset type in each industry averaged over two years. Property income in each industry is allocated to asset types by employing estimates of the "implicit rental prices" of each asset type. Because some asset types tend to deteriorate much more quickly than others and because of tax rules that are specific to asset types, the economic cost (rental price) of employing a dollar's worth of stock varies substantially by asset type.

The distinction between labour input and labour hours is analogous to the distinction between capital services and capital stock. Growth in labour input reflects the increase in labour hours, as well as changes in the composition of hours worked as firms substitute among heterogeneous types of labour.

Both Canada and the US make use of the same concept of labour input in their business sector estimates of multifactor productivity. Canada makes use of household survey data to disaggregate total hours into hours worked by different types of workers classified by demographic variables such as age and education. Labour input is calculated as a weighted sum of hours worked by different types of workers to take into account differences in labour composition; the weights are defined in terms of relative wage rates.

At the level of the business sector, the BLS breaks the hours worked down into three categories – educational attainment, work experience, and gender. Statistical regression techniques are used to remove the impact of other worker characteristics such as marital status on average wage rates in each of these three groups. The BLS then uses predicted wage rates for each of the categories. Canada uses educational attainment, age and worker type for its groupings and uses average wage rates in each of the categories as weights without correcting for other worker characteristics.[18] In contrast to the practice followed for the business sector, US labour input for manufacturing is measured as the sum of hours at work of all persons. Therefore, in order to provide cross-country comparability in this study, Canadian labour input estimates both for the business sector as a whole and for the manufacturing sector were brought to the lowest common denominator, which is the straight sum of hours worked.

Hence, this study uses the notion of labour input for the decomposition of economic growth and labour productivity growth at the business sector level. In contrast, due to the lack of data on labour input for US industries, the analysis of the sectoral allocation of aggregate productivity growth requires the use of the notion of hours at work. In the latter case, data on hours for both Canada and the US are directly aggregated across all worker groups and the resulting growth rates that are calculated from this sum do not include the effects of changing labour composition.

CANADA-US ESTIMATES OF INFORMATION TECHNOLOGY CONTRIBUTIONS COMPARED

Motivation

This section explores the contribution of information technology to Canada's real GDP, capital input and productivity growth. The information technology contributions to output growth are assessed over output cycles, which are defined as periods between peaks in GDP growth. The peaks are defined as points where the gaps between the actual and a trend output series turn from increasing to decreasing. The use of output cycles is one method for defining and examining underlying trends in output growth.

A number of studies, including those reviewed in the introduction, have compared growth rates for the second half of the 1990s with earlier periods. The use of 1995 as the dividing point between these periods may be defensible in terms of delineating the acceleration in investment in information technology from 1995, due to the change in the life cycle of semiconductors. But these periods are essentially arbitrary with respect to productivity growth and would only accidentally reveal underlying trends for analysis in the growth accounting framework. (Comparisons of contributions in the two halves of the 1990s are nevertheless presented below because of the general tendency of the literature to do so.)

There is some disagreement about the extent to which the measured acceleration represents an uplift in the underlying trend rate of growth or merely a transient or cyclical effect. For the US, Gordon (2000) believes that there is a sizeable cyclical component in the productivity acceleration and has made an adjustment to extract it. He believes that the extent of the reduction in unemployment and the increase in the current account deficit in the 1990s make the high rate of output and productivity growth unsustainable. Gordon's treatment has attracted some controversy. But, on the other hand, most other studies do not explicitly consider the issue, and report measured productivity accelerations as though they are trend shifts.

In this paper, we use the Hodrick-Prescott technique to distinguish the trend from the cyclical component. The common use of the Hodrick-Prescott filter has been criticised, particularly for the accuracy of trend calculations at the start and end of series. But it can be reasonably used here to show that for Canada and the US, the appropriate periods are 1981-1988 and 1988-2000 and the year 1995 was above the trend.

Aggregate trends

This section examines the contributions of information technology to the aggregate output and inputs in Canada and the United States. It also highlights and updates several trends, some of which were already reported in Harchaoui *et al.* (2002) for the 1981-1999 period.

Contributions to GDP *growth*

The top panel of Tables 3*a* and 3*b* summarises for Canada and the US, respectively, the growth rates of prices and quantities for information technology-GDP and for everything else, labelled non-information technology GDP, during the 1981-2000 period. The most striking feature of the data is the rapid increase in information technology-GDP, 13.3% per year from 1981 to 2000, compared with a modest 2.6% for non-information technology-GDP (13.7% and 3%, respectively, for the United States). Since 1995, information technology-GDP grew 22.3% per year in Canada, more than five times the increase experienced by non-information technology GDP (23.7% per year for the United States).

Table 3*a*. **General trends in GDP and primary inputs, Canadian business sector**

	1981-2000		1981-1988		1988-2000		1988-1995		1995-2000	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
GDP	2.8	3.1	4.3	3.3	1.9	2.9	2.1	1.5	1.7	5.0
IT[1] GDP	–3.1	13.3	–0.5	10.2	–4.6	15.2	–5.4	10.4	–3.6	22.3
IT – consumption	–0.1	8.3	2.3	7.8	–1.5	8.6	–1.3	7.1	–1.6	10.7
IT – investment	–6.6	17.8	–6.3	18.2	–6.8	17.5	–6.9	14.2	–6.6	22.3
IT – other	–7.2	16.6	–10.1	25.9	–5.6	11.5	–4.1	14.2	–7.6	7.8
Non-IT GDP	3.1	2.6	4.5	3.0	2.2	2.4	2.4	1.2	2.0	4.2
Capital services	2.8	3.3	4.3	3.4	1.9	3.3	1.5	2.5	2.4	4.3
IT	–6.1	17.2	–4.1	18.0	–7.2	16.8	–9.0	15.7	–4.6	18.4
Computers	–14.9	28.6	–14.4	28.5	–15.1	28.7	–16.8	25.7	–12.8	32.9
Software	3.5	8.6	8.5	5.8	0.7	10.3	–2.0	9.0	4.5	12.2
Tele-communications	–1.7	12.5	4.0	17.2	–4.9	9.8	–6.7	11.7	–2.3	7.2
Other machinery and equipment	3.2	3.1	6.0	3.7	1.6	2.8	2.0	1.4	1.1	4.8
Structures	3.7	2.0	4.5	2.1	3.2	1.9	2.6	1.5	4.1	2.3
Labour input	3.2	2.4	4.7	2.8	2.4	2.2	2.2	1.2	2.7	3.6
Hours at work	1.6		2.0		1.4		0.3		3.1	
Labour composition	0.8		0.8		0.8		1.0		0.5	
Memo ($ million)			**1981**		**2000**					
Total capital stock[2]			492 588		1 278 237					
Fixed reproducible capital stock[2]			290 465		929 409					
IT			11 363		59 900					
Business sector nominal GDP			258 873		770 562					
Labour compensation			158 736	61.3%	457 198	59.3%				
Capital compensation			10 138	38.7%	313 364	40.7%				

1. IT: Information technology.
2. Canadian Productivity Accounts.

The more rapid growth of information technology-GDP can be understood by examining the behaviour of relative prices. The rate of inflation of the non-information technology-GDP deflator in Canada declined from 4.5% per year in the 1980s to 2.2% per year in the 1990s (from 3.7% to 2.7% for the United States). The quality-adjusted price of information technology GDP fell more rapidly during the 1990s, compared with the 1980s (–4.6% compared with –0.5% for Canada; –5.0% compared with –2.2% for the United States). Relative to the non information technology-GDP deflator, information technology-GDP prices fell at an average of –6.8% in the 1990s, compared with –5.0% during the 1980s (–7.7% compared with –5.9% for the United States).

Table 3*b*. **General trends in GDP and inputs, US business sector**

	1981-2000		1981-1988		1988-2000		1988-1995		1995-2000	
	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity
GDP	2.7	3.6	3.4	3.5	2.2	3.6	2.8	3.0	1.4	4.5
IT[1] GDP	–4.0	13.7	–2.2	12.2	–5.0	14.6	–3.6	10.4	–6.9	20.6
IT – consumption	–2.2	11.6	2.2	8.0	–4.6	13.7	–2.6	11.1	–7.4	17.5
IT – investment	–4.8	15.8	–3.4	13.9	–5.5	16.9	–4.1	12.2	–7.6	23.7
IT – other	–6.6	19.3	–8.5	15.3	–3.2	21.8	–4.7	–7.0	–9.2	77.6
Non-IT GDP	3.1	3.0	3.7	3.0	2.7	3.0	3.2	2.6	2.0	3.5
Capital services	2.4	3.9	4.0	3.9	1.6	3.9	2.1	2.8	0.8	5.4
IT	–4.5	16.5	–3.7	19.5	–5.0	14.8	–1.5	10.3	–9.6	21.3
Computers	–13.2	28.1	–12.0	34.0	–13.9	24.8	–8.0	13.8	–21.5	41.8
Software	–0.8	15.4	1.0	15.7	–1.7	15.2	–1.4	14.3	–2.3	16.4
Tele-communications	1.6	6.8	3.5	8.1	0.5	6.1	4.1	4.4	–4.3	8.5
Other machinery and equipment	4.6	1.9	6.3	1.4	3.6	2.2	4.3	1.5	2.8	3.1
Structures	3.1	2.3	4.1	2.9	2.4	1.9	1.9	1.7	3.1	2.2
Labour input	4.0	2.2	4.7	2.4	3.6	2.1	3.0	1.8	4.5	2.4
Hours at work	1.7		1.9		1.5		1.2		2.0	
Labour composition	0.5		0.5		0.5		0.6		0.4	
Memo ($ million)			**1981**		**2000**					
Total capital stock[2]			8 685 677		19 412 347					
Fixed reproducible capital stock[2]			5 943 138		13 738 125					
IT			244 589		1 217 850					
Business sector nominal GDP			2 215 871		7 110 466					
Labour compensation			1 510 872	68.2%	4 808 844	67.6%				
Capital compensation			704 999	31.8%	2 301 622	32.4%				

1. IT: Information technology.
2. Canadian Productivity Accounts.

Investments in information technology increased almost as rapidly in the 1990s as in the 1980s in Canada (17.5% compared with 18.2%), in sharp contrast with the US where growth was more rapid in the 1990s (16.9% compared with 13.9% during the 1980s). The rapid increase in the 1990s is largely attributable to the performance during the post-1995 period where information technology investment increased 22.3% per year in Canada (23.7% in the United States). Households' expenditures in information technology increased 8.6% during the 1990s (13.7% in the US), a more rapid pace than in the 1980s, particularly in the United States.

This moderate increase in information technology household spending is largely due to information technology consumer prices that reflect only partly the quality change observed for information technology investment. Information technology net exports, the main component of the category Other Information Technology, shows a consistent decline in the quantity, reflecting Canada's net importer status for information technology goods over the last two decades. The relatively rapid increase of information technology imports over exports is in part attributable to the decline of information technology import prices relative to export prices in Canada.

Panel B of Table 4 shows the share of information technology GDP in overall business sector GDP – defined as the ratio of the expenditure on information technology over total expenditures in current prices. The share was 2.7% in the 1980s in Canada (5.1% in the US), but has risen fairly steadily and reached 4.0% in the late 1990s (6.1% in the United States).

Recall that the contribution of information technology to GDP growth is the share of final output of information technology in GDP multiplied by the growth rate of information technology-GDP. The data show that despite its small share in GDP in both Canada and the US, information technology accounted for almost 18% of GDP growth in Canada during the 1995-2000 period (27.8% for the US), up from the 8.6% contribution made during the 1981-1988 period (17.3% for the United States). The information technology contribution is clearly rising. The rising level of the information technology contribution is due to information technology GDP growing more rapidly in the last decade, but also to the steadily rising information technology share.

Contributions to the capital input growth

This section presents the information technology contribution to capital input for the Canadian and US business sectors for the period 1981-2000. The stock of information technology business assets (computers, software, and communications equipment) has grown dramatically in recent years, but remains relatively small. In 2000, combined information technology assets accounted for only 4.2% of the Canadian tangible capital and 6.4% of reproducible private assets (6.3% compared with 8.9% for the US), up from 2.3% and 3.9%, respectively, in 1981 (2.8% compared with 4.1% for the US) (see bottom panel of Tables 3*a* and 3*b*).

Tables 3*a* and 3*b* highlight the rapid increase in the importance of information technology assets in Canada and the US, reflecting the accelerating pace of relative price declines. In the 1990s, the service price for information technology assets fell 7.2% per year (5.0% for the US), compared with an increase of 1.6% and 3.2%, respectively, for other machinery and equipment and structures capital (3.6% and 2.4% for the United States). As a direct consequence of this relative price

Table 4. **Sources of growth GDP and capital services, business sector (percentage)**

	1981-2000		1981-1988		1988-2000		1988-1995		1995-2000	
	Canada	US	Canada	US	Canada	US	Canada	US	Canada	US
A. Capital input and its components	Average annual growth rate									
Capital services	3.3	3.9	3.4	3.9	3.3	3.9	2.5	2.8	4.3	5.4
Information technology	17.2	16.5	18.0	19.5	16.8	14.8	15.7	10.3	18.4	21.3
Computer	28.6	28.1	28.5	34.0	28.7	24.8	25.7	13.8	32.9	41.8
Software	12.5	15.4	17.2	15.7	9.8	15.2	11.7	14.3	7.2	16.4
Telecommunications	8.6	6.8	5.8	8.1	10.3	6.1	9.0	4.4	12.2	8.5
Other machinery and equipment	3.1	1.9	3.7	1.4	2.8	2.2	1.4	1.5	4.8	3.1
Structures	2.0	2.3	2.1	2.9	1.9	1.9	1.5	1.7	2.3	2.2
	Average cost of capital share of assets									
Capital services	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Information technology	6.8	12.0	5.5	8.9	7.6	13.9	7.1	12.9	8.3	15.3
Computers	39.0	31.9	43.1	35.4	36.5	29.9	35.4	30.0	38.0	29.2
Software	28.2	31.8	19.4	26.6	33.6	34.6	33.1	32.0	34.7	38.2
Telecommunications	32.8	36.4	37.5	38.0	29.9	35.5	31.5	38.0	27.3	32.6
Other machinery and equipment	24.7	29.1	24.3	28.5	25.1	29.5	25.2	28.9	25.0	30.5
Structures	68.4	58.8	70.2	62.5	67.2	56.6	67.7	58.2	66.7	54.3
B. GDP and its components	Average annual growth rate									
GDP	3.0	3.6	3.3	3.6	2.9	3.6	1.5	3.0	4.9	4.5
Information technology GDP	13.5	13.7	10.5	12.2	15.3	14.6	10.3	10.4	22.6	20.6
Non-Information technology GDP	2.7	3.0	3.1	3.1	2.4	3.0	1.2	2.6	4.2	3.5
	Average nominal GDP share of output components									
GDP	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Information technology GDP	3.2	5.6	2.7	5.1	3.5	5.8	3.1	5.2	4.0	6.1
Non-information technology GDP	96.8	94.4	97.3	94.9	96.5	94.2	96.9	94.8	96.0	93.9

change, information technology capital services grew 16.8% (14.8% for the US), compared with only 2.8% and 1.9% for the services of other machinery and equipment and structures in the 1990s (2.2% and 1.9% for the United States).

The rapid accumulation of information technology, however, appears to have different origins. During the 1990s, the prices of telecommunications and software investments have declined much more slowly, –2.0% and –3.1% per year, respectively, *versus* –14.9% for computers (–1.5%, –0.3% and –16.0%, respectively, for the United States). This decline in investment prices was not strong enough to lead to a rapid decline in service prices for telecommunications and software capital assets, –4.9% and 0.7%, respectively (0.5% and –1.7% in the United States). Nonetheless, industries have been accumulating telecommunications and software quite rapidly, with real capital services growing 9.8% and 10.3% per year in the 1990s, respectively for these two assets (6.1% and 15.2% in the United States). Complementarity between telecommunications, software and computers is one possible explanation. Industries responded to the decline in relative computer prices by accumulating computers and investing in complementary inputs like telecommunications equipment and software to put the computers into operation.

While information technology assets are about 4% of total capital in Canada in the late 1990s (compared with about 2% in the 1980s) (respectively 3% and 6% for the US) (results not reported), the information technology service shares, or the cost of capital shares, of these assets are twice as high as the corresponding asset shares (see Panel A of Table 4). In the late 1990s, it was 8.3% compared with 5.5% during the 1980s (15.3% compared with 8.9% in the United States). This reflects the rapid price declines and high depreciation rates that enter into the rental prices for information technology.

Table 4 also shows that information technology as a production input which saw its contribution rising even more dramatically than the GDP side. Information technology capital services contributed 36% to the growth of broadly defined capital during the late 1990s, up from 29% during the 1980s (60% compared with 45% for the United States). Computers are the single largest information technology contributor on the input side, which reflects the growing share and rapid growth rates of the late 1990s. Price changes lead to substitution toward capital services with lower relative prices such as computers.

During this period, GDP prices rose 1.7% in Canada (1.4% in the US), compared with a 4.6% price decline of information technology capital services (9.6% decline for the US) (see Tables 3*a* and 3*b*). In response to these price changes, industries accumulated computers, software, and telecommunications equipment more rapidly than other forms of capital. Investment other than information technology actually declined as a proportion of GDP. These substitutions suggest that gains of the computer revolution accrue to industries and households who restructured their activities to respond to these relative price changes.

Contribution to productivity growth

We now turn to assess the contribution of information technology to capital deepening and to see how much of the growth of labour productivity it can account for, based on the standard decomposition of labour productivity growth – capital deepening, labour composition and multifactor productivity growth. Tables 5*a* and 5*b* reflect, respectively, the major sources of the Canadian and US business sector labour productivity growth.

The 1.3% average annual growth of Canadian labour productivity during the 1980s (1.9% for the US) is attributable to a modest growth of multifactor productivity (0.3 percentage point in Canada, compared with 0.9 percentage point for the US), but a rather rapid increase of both capital deepening (0.6 percentage point for both countries) and labour composition (0.5 percentage point in Canada compared with 0.3 percentage point for the United States).

Labour productivity growth increased moderately to 1.5% during the 1990s (2.0% for the US) solely as a result of the rapid increase of capital deepening, while the percentage point contribution of multifactor productivity and labour composition remained unchanged from the previous decade (0.3 and 0.5 percentage point, respectively).

The first and the second halves of the 1990s portray some features that are worth noting. In both countries, the growth of labour productivity slipped during the 1988-1995 period in comparison with the previous decade with the serious slump in multifactor productivity only partly offset by a revival in the growth of capital deepening in Canada (0.8 percentage point) and labour composition in both Canada and the United States.

In Canada, labour composition grew at 0.6% during the 1988-1995 period (compared with 0.5% during the 1981-1988 period) (0.4% compared with 0.3%, respectively, for the US), while hours at work advanced at 0.3% (1.2% for the US) (2% and 1.9 for Canada and the US, respectively, during the previous decade) (see Tables 5*a* and 5*b*). This increase of labour composition in a period of economic slump may reflect the tendency of firms at the beginning of an economic recession to lay off workers with the least seniority ("last-hired first fired"). Blue-collar workers usually experience more layoffs than well-educated white-collar workers do. As the expansion continues as in the post-1995 period, however, firms often hire workers with lesser qualifications and workers who were not previously in the labour force, with a resulting decline in labour composition.

Canada's labour productivity growth advanced at 1.8% on average during the 1995-2000 period (2.7% for the US) due primarily to the resurgence of multifactor

Table 5*a*. **Compound average annual rates of labour productivity and the contributions of capital intensity, labour composition and multifactor productivity, Canadian business sector**

Percentage

	1981-2000	1981-1988	1988-2000	1988-1995	1995-2000
Labour productivity	1.4	1.3	1.5	1.2	1.8
Capital deepening	0.6	0.6	0.7	0.8	0.5
Information technology	0.4	0.3	0.4	0.4	0.5
Computers	0.3	0.2	0.3	0.2	0.4
Software	0.1	0.1	0.1	0.1	0.1
Communication	0.1	0.0	0.1	0.1	0.1
Other machinery and equipment	0.1	0.2	0.1	0.1	0.2
Structures	0.1	0.1	0.1	0.3	–0.2
Labour composition	0.5	0.5	0.5	0.6	0.3
Multifactor productivity	0.3	0.3	0.3	–0.2	1.1

N*ote*: The numbers may not add up due to rounding.

Table 5*b*. **Compound average annual rates of labour productivity and the contributions of capital intensity, labour composition and multifactor productivity, US business sector**

Percentage

	1981-2000	1981-1988	1988-2000	1988-1995	1995-2000
Labour productivity	1.9	1.9	2.0	1.4	2.7
Capital deepening	0.7	0.6	0.8	0.5	1.1
Information technology	0.6	0.5	0.6	0.4	1.0
Computers	0.3	0.3	0.3	0.2	0.6
Software	0.1	0.0	0.1	0.0	0.1
Communication	0.2	0.1	0.2	0.2	0.2
Other machinery and equipment	0.0	0.0	0.1	0.0	0.1
Structures	0.1	0.2	0.1	0.1	0.0
Labour composition	0.3	0.3	0.3	0.4	0.3
Multifactor productivity	0.9	0.9	0.9	0.5	1.4

N*ote*: The numbers may not add up due to rounding.

productivity growth which contributed 1.1 percentage points (1.4 percentage points in the US), while capital deepening added 0.5 percentage point , somewhat lower than during the 1988-1995 period. This contrasts with the US, where capital deepening contribution more than doubled between the early and the late 1990s. Growth in labour composition slowed, particularly in Canada, as growth in hours accelerated. This reflects the falling unemployment rate and tightening of labour markets as more workers with relatively low marginal products were drawn into the workforce.

Tables 5*a* and 5*b* shows that since 1981 information technology has contributed around two-thirds of the 0.6% increase in deepening in Canada (more than four-fifth of the 0.7% increase in the United States). In the early 1980s, information technology contributed half of the 0.6 percentage point increase in capital deepening in Canada (more than four-fifths for the 0.6 percentage point increase for the United States). Its contribution slipped back in 1988-1995 in Canada, but in the latest period, 1995-2000, it contributed to all of the 0.5% increase of capital deepening (90% of the 1.1% increase in the United States). This suggests that capital deepening grew exceptionally faster during the late 1990s in the US, largely as a result of information technology.

The sources of economic growth

To provide a different perspective on the contribution of information technology, we now focus on the sources of GDP growth. Using the framework developed above, the capital and labour inputs are combined with output data to estimate the components of Equation [2] to quantify the sources of economic growth in GDP from 1981-2000. In addition to the standard contribution of aggregate capital services, the analysis also examines the contribution of each broad asset class to economic growth.

The results are reported in Table 6. For the period 1981-1988, output grew at 3.3% per year in Canada (3.9% in the US), of which aggregate capital services contributed 1.4 percentage points (1.3 percentage points in the US), labour input 1.7 percentage points (1.6 percentage points in the US), and multifactor productivity 0.2 percentage point (0.9 percentage point in the United States). The 1.4 percentage point contribution of capital services is largely driven by information technology and other machinery and equipment (altogether 0.8 percentage point). This contrasts somewhat with the US where information technology and structures contributed 1.1 percentage points to the growth of capital input.

For 1995-2000, GDP grew 5.0% per year in Canada (4.8% for the US), capital services contributed 1.7 percentage points (1.8 percentage points for the US); a little more than one-third of this is due to information technology (compared with slightly less than two-thirds for the United States). Labour input contributed 2.2 percentage points (1.6 percentage points for the US), and multifactor productivity added the remaining 1.1 percentage points (1.4 percentage points for the United States).

The second half of the 1990s, compared with the first half, is remarkable. For the 3.5 percentage points acceleration (difference between the late and early 1990s) of GDP in Canada (2.1 percentage points in the US), labour input added 1.4 percentage points (0.4 percentage point for the US), followed by multifactor productivity with 1.3 percentage points (0.9 percentage point in the US), and capital

Table 6. **Sources of business sector GDP growth, Canada-US**
Percentage

	Canada					United States				
	1981-2000	1981-1988	1988-2000	1988-1995	1995-2000	1981-2000	1981-1988	1988-2000	1988-1995	1995-2000
GDP	3.1	3.3	2.9	1.5	5.0	3.7	3.9	3.6	2.7	4.8
IT GDP	0.4	0.3	0.5	0.3	0.9	0.7	0.6	0.8	0.5	1.3
Non-IT GDP	2.6	3.0	2.4	1.2	4.1	2.9	3.2	2.8	2.2	3.5
Contribution of capital services	1.3	1.4	1.3	1.0	1.7	1.3	1.3	1.3	0.9	1.8
Information technology	0.5	0.4	0.5	0.4	0.6	0.6	0.5	0.7	0.4	1.1
Computer	0.3	0.3	0.3	0.2	0.4	0.4	0.3	0.4	0.2	0.6
Software	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3
Telecommunications capital	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Other machinery and equipment	0.3	0.4	0.3	0.2	0.5	0.2	0.1	0.2	0.1	0.3
Structures	0.5	0.6	0.5	0.4	0.6	0.4	0.6	0.4	0.3	0.4
Contribution of labour input	1.5	1.7	1.4	0.8	2.2	1.5	1.6	1.4	1.2	1.6
Multifactor productivity growth	0.3	0.2	0.3	–0.2	1.1	0.9	0.9	0.9	0.5	1.4

services with 0.7 percentage point (0.9 percentage point for the United States). This increase in the contribution of capital services in the US during this period is due in a large part to information technology (0.7 percentage point). This contrasts with Canada where the contribution of all three asset classes have all equally contributed to the revival of capital input.

The revival of multifactor productivity is a major source of growth in GDP and labour productivity growth for the Canadian and US business sectors. While multifactor productivity growth for the 1990s has yet to attain the peaks of some periods in the golden age of the 1960s and early 1970s, the recent acceleration suggests that the Canadian business sector may be recuperating from the anaemic productivity growth of the past two decades. Of course, caution is warranted until more historical experience is available.

SECTORAL SOURCES OF CANADA AND US PRODUCTIVITY REVIVAL

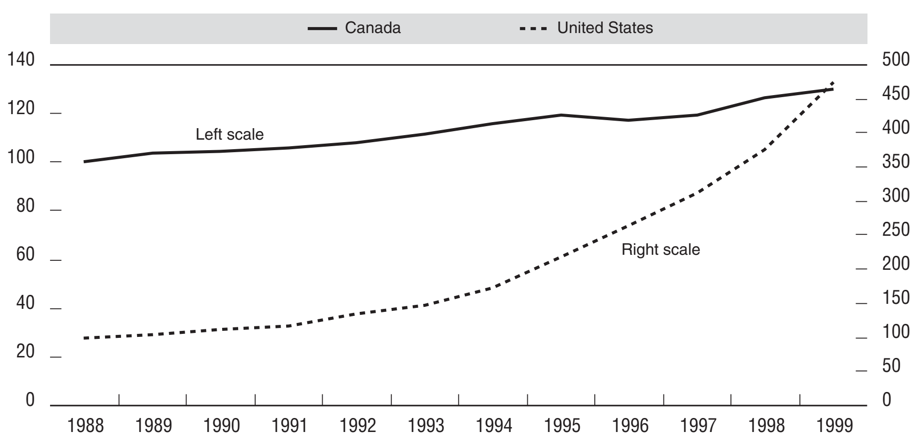
We have explored the sources of the Canada-US economic growth at the aggregate level and demonstrated that the acceleration in multifactor productivity growth is an important contributor to the recent growth resurgence. We now examine how information technology-producing and information technology-using industries contributed to the acceleration of aggregate multifactor productivity growth in the Canada-US productivity revival. We base our analysis of information technology-producing industries on the most comparable data that are also consistent with the aggregate trends illustrated above. The analysis also uses KLEMS data available through 1999 at the most detailed industry level of Canada and US SIC systems. The advantage of using this detailed data set is twofold: first, it minimises the impact of the differences in the industrial structures between these two countries and, secondly, it provides reasonably more precise estimates of the contribution of the information technology-producing industries to business sector multifactor productivity growth.

These data are based on the notions of sectoral output and capital services. In contrast, due to data limitations, US labour input for manufacturing is measured as the sum of hours at work of all persons. As a result, to maintain cross-country comparability for this study, Canadian labour input estimates were brought to the lowest common denominator, which is the straight sum of hours worked. For this particular reason, the multifactor productivity estimates of the Canadian and US business sectors used in this section are not directly comparable with those discussed in the previous section. In particular, the multifactor productivity gains should be higher because they include the labour composition effect.

Figure 1 reports the Canada-US estimates of multifactor factor productivity growth for information technology-producing industries from 1988 to 1999, the period that is closely comparable to the one used in the analysis of the aggregate trends. Over this period, multifactor productivity growth of Canadian information technology-producing industries advanced at 2.4% on average, a much slower increase than that of the US, which grew at 15.2%.

Figure 1. **Multifactor productivity trends of information technology-producing industries**

1988 = 100



For the 1995-1999 period, Canadian information technology-producing industries advanced at 2.1% on average, down from 2.6% during the early 1990s. In contrast, the productivity performance of US information technology-producing industries, which grew at 11.8% on average during the early 1990s, almost doubled by the late 1990s (21.3%). As evidenced by Figures 2 and 3, there are some similarities between Canada and US: hours at work showed a moderate declining trend in both countries (–0.4% and –0.2%, respectively) but capital services grew slightly more rapidly in Canada than in the US (9.1% compared with 7.7%).

But there are also major differences that are worth noting. The major difference between the two countries is ascribed to the trends of sectoral output and sectoral intermediate inputs. Canada's sectoral output grew significantly less rapidly that its US counterpart (14.2% compared with 21.9%) and *vice versa* for the sectoral intermediate inputs (16.4% compared with 7.3%), with the result that Canada posted a negative average growth rate for the productivity of sectoral intermediate inputs compared with major efficiency gains for the US (–4.2% and 14.6%, respectively).

These diverging trends in the productivity of sectoral intermediate inputs between the two countries are due to both structural and measurement differences. First, Canada imports a significant amount of information technology products that are reflected in the sectoral intermediate inputs. The prices of these products are adjusted for quality change with the result that the sectoral

Figure 2. **Chained volume indexes for Canada's information technology-producing industries**

1988 = 100

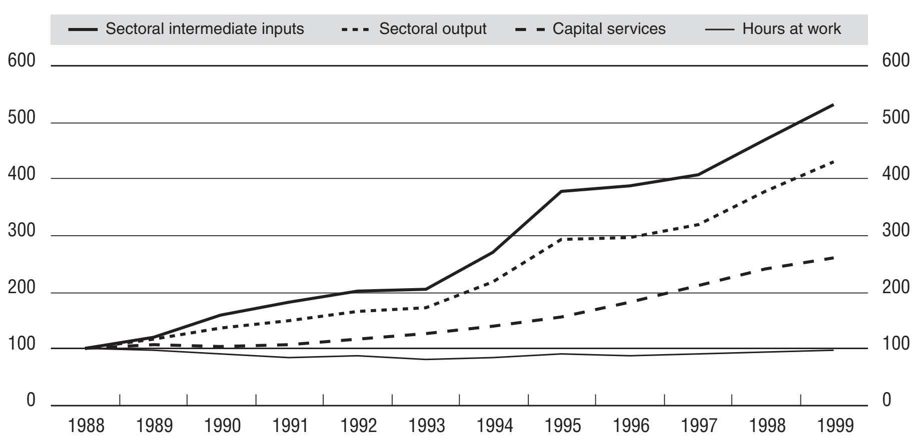
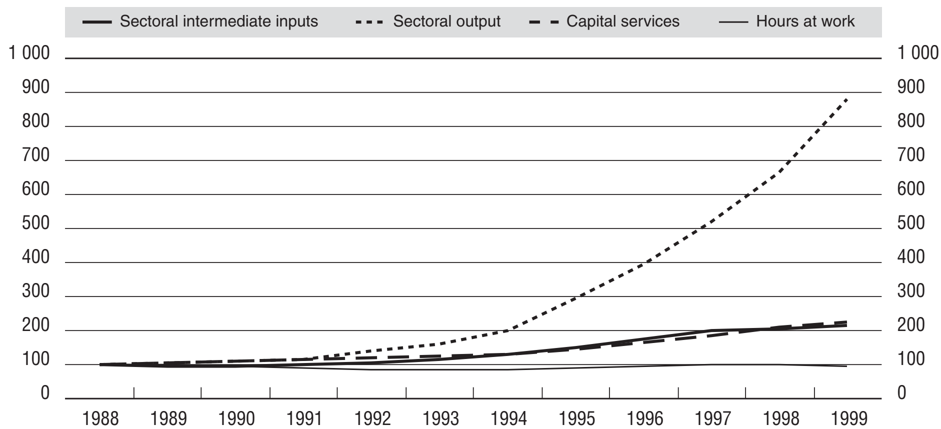


Figure 3. **Chained volume indexes of US information technology producing-industries**

1988 = 100



intermediate inputs experience a remarkable increase. In contrast, the same products are netted out for the US intermediate inputs. Second, the output implicit price index of communication equipment industry shows a diverging trend between the two countries while that of electronic products and accessories declined at a slower pace in Canada compared with the United States. This translates in a slower Canadian output growth for these two industries, compared with the United States.

Table 7 reports the sectoral sources of business sector multifactor productivity growth decomposition estimates. Over the 1988-1999 period, out of the 1.08% average US multifactor productivity growth, information technology-producing industries contributed 0.62 percentage point, or 57.6%. For the early 1990s, these industries contributed for 49.8% to the 0.88% average annual increase of the US business sector multifactor productivity growth. In contrast, for 1995-1999, two-thirds of the 1.43% surge in the US multifactor productivity growth is ascribed to information technology-producing industries, a sharp contrast with most of the US literature findings. This difference in the results is due to the fact that the majority of US studies have used a two-digit SIC that tends to mix information technology-producing industries with electrical industries, an approach that mitigates the contribution of information technology-producing industries. In the case of some studies, such as CEA (2001), this problem with the industry structure is magnified with the use of gross product originating output, a measure that tends to overestimate the contribution of information technology-using industries. This is so because gross output originating is based on the income side of national income

Table 7. **Sectoral contributions to aggregate multifactor productivity growth, 1981-1999**

	Canada			United States		
	1988-1999	1988-1995	1995-1999	1988-1999	1988-1995	1995-1999
Multifactor productivity growth of the business sector	0.73	0.42	1.28	1.08	0.88	1.43
Information technology-producing industries	0.071 (10.2%)	0.072 (17.3%)	0.068 (6.1%)	0.62 (57.6%)	0.44 (49.8%)	0.94 (66%)
Information technology-using industries	0.66	0.35	1.21	0.46	0.44	0.49

Notes: The estimates of multifactor productivity are based on the concept of sectoral output and hours at work. Therefore, they are not directly comparable to those presented in Table 5 for Canada. With the exception of the numbers in parentheses, all other numbers are average annual growth rates. The numbers in parentheses represent the contribution of information technology-producing industries to business sector multifactor productivity growth.

accounts, a measure that makes the productivity revival larger as the estimated income grew more rapidly than the estimated product accounts.[19] Given the still relatively small size of the computer and semiconductor sectors, this contribution is substantial and highlights the important impact that information technology is having on the US business sector.

While information technology-producing industries are at the centre stage of the US productivity revival, Canada's experience offers a different story as almost all of its productivity resurgence is due to information technology-using industries. Whilst intensive information technology-using industries contributed most to Canada's productivity surge in the 1990s, even in those industries, some of the gains are likely to be due to factors such as industry-specific factors. Some detailed comparisons would be needed to distinguish conclusively between these two possibilities.

In terms of the sectoral sources of the multifactor productivity resurgence between the early and the late 1990s, the results are even more startling: out of the 0.55 percentage point increase in the US multifactor productivity between these two periods, information technology-producing industries contributed 0.5 percentage points (91%), which leaves the contribution of information technology-using industries at 9%, quite modest in comparison to the estimates produced by the US productivity literature (see Table 5 above). Our results, therefore, tend to support Gordon's point of view, which gives all of the multifactor productivity gains to information technology production. For Canada, however, the story stands in contrast with the US experience as all of the 0.86 percentage point increase in multifactor productivity acceleration between 1988-1995 and 1995-1999 is due to gains that occurred in information technology-using industries.

Before proceeding to the sources of Canada-US differences in terms of the impact of information technology, it is useful to compare our results based on a "top down approach" to those based on a "bottom up approach" reported by Bosworth and Triplett (2004) who found that much of the post-1995 multifactor productivity resurgence stemmed from non information technology-producing industries, particularly services-producing industries. While a full reconciliation between these results is beyond the scope of this paper, we can still trace some of the sources of this apparent conflicting message across these studies. First, our measure of output at the aggregate level is based on the expenditure side of the accounts, compared with a measure of output based on the income side of the accounts for Bosworth and Triplett, two concepts that are not reconciled under the US economic accounts. Second, under the industrial detail used by Bosworth and Triplett, computers industry is mixed with electrical machinery in SIC 35, industrial machinery and equipment. Electrical machinery industry is significantly larger than computers industry but in terms of productivity performance the latter has outperformed the former. This has resulted in a possible downward bias of the sectoral contribution of information technology-producing industries. Our use of the three digit industry detail data avoids this problem.

MORE ON CANADA-US DIFFERENCES

Having covered the basic results from the growth-accounting exercise, we now turn to two sets of questions: First, why has the information technology effect in Canada not been as large as in the United States? This question is addressed at both the aggregate and industry levels. Second, what is the productivity outlook during the post-2000 period?

The sources of the difference in information technology

As stated above, the contribution to output growth of any sector is its share in GDP (in current prices) multiplied by the growth rate of its final output. So the effect of information technology output depends on both on its GDP share and its growth. A similar point applies to the input side. Here the contribution of information technology capital services to the growth of aggregate input is the share in GDP of the cost of capital attributable to information technology capital, multiplied by the growth rate of information technology capital services.

There is a discernible pattern across different sub-periods of the last two decades for the aggregate trends of information technology-GDP and information technology capital services between Canada and the United States. As indicated by Tables 3*a* and 3*b*, during the 1980s, the US information technology capital services grew at a faster pace than its Canadian counterpart, and *vice versa* for the 1990s. A similarly pattern is revealed by the information technology-GDP trends in both countries with the result that, over the 1981-2000 period, both information technology-GDP and information technology capital services grew almost at the same pace in Canada and United States. However, over the same period, there are significant differences in terms of the share of information technology in both capital compensation and nominal GDP in favour of the United States. This may underline some differences in the technological structures between the two countries.

Specifically, what determines that the order of magnitude of the share of output generated by information technology capital is higher or lower and hence whether, for a given growth rate of information technology capital, the contribution to aggregate input is higher or lower is the elasticity of substitution between information technology capital and other inputs.[20] The US information technology output and capital shares are higher than their Canadian counterparts, which suggests that that this elasticity in the US has apparently been greater than in Canada (at least at the business sector level). Additional research outside the growth accounting framework is therefore warranted to substantiate this possible structural difference between Canada and the United States.

At the disaggregated level, there are some indications that output and intermediate price measurement differences between Canada and US in telecommunication and, to a lesser extent, electronic products and accessories, are not negligible. On the sectoral output side, the output implicit price index has diverged between Canada and US for telecommunication industries (respectively, 1.4% compared with –2.5% for the United States). However, for electronic products and accessories, the implicit prices have declined for both countries, albeit at a different pace (–2.6% for Canada and –11.5% for the United States). These price differences are compounded by the difference in the share of each of these industries between Canada and Unites States.

On the input side, recall that sectoral intermediate inputs are purchased from outside the manufacturing sector and, as a result, they include imported information technology products for Canada and non-information technology products and services for the United States. In principle, Canadian sectoral intermediate input price indexes should decline at a much more rapid pace than their US counterparts. But the data show that this is not the case. Sectoral intermediate input prices indexes advanced at 0.3% and –2.2%, respectively, for the two Canadian industries, compared with 0.7% and –0.25% for their US counterparts.

The different price behaviour between Canada and the US in telecommunication equipment and electronic products and accessories, led us to explore further the impact of using different deflators on the productivity performance of communications and electronic product industry, an aggregate of telecommunication equipment industry and electronic products and accessories industry.

Suppose hypothetically that the price indexes of Canadian sectoral output and sectoral intermediate inputs for the communication and electronic product industry decline at the same pace as that of sectoral output for its US counterpart, corrected for the exchange rate.[21] What would then be the impact on multifactor productivity performance trend for this industry?

In this case, the implicit price indexes of sectoral output and sectoral intermediate inputs would advance, respectively, at –5.5% (compared with –0.14% before correction) and –2.7% (compared with 0.14% before correction). These changes would increase the growth of sectoral output and sectoral intermediate inputs. The adjustment to multifactor productivity growth would correspond to the adjusted growth of sectoral output net of the adjusted growth of sectoral intermediate inputs weighted by the share of sectoral intermediate inputs in the total cost. Once these adjustments are implemented, multifactor productivity growth of the Canadian communication and electronic product industry would increase from 1.5% to 5.5% over the 1988-1999 period (11.4% to 17.7% for labour productivity growth), but still remains below that of the US which grew at 15.2%. But given the modest size of this industry in the business sector, our initial conclusion still stands – Canada's productivity revival is largely attributable to information-using industries – but the contribution of information technology-producing industries jumps from 7.1% to 21.6% once the price adjustment is made.

The recent productivity outlook

The recent years have experienced a fall in information products, reflecting the collapse of stock prices of many technology firms and the dry up of their sources of financing. The economic impacts of the events of September 11 and the rally in the Canadian dollar both add to the considerable uncertainties about future growth of the Canadian economy. These developments also raise legitimate questions about the robustness of the productivity pick up in Canada and United States observed over the 1995-2000 period.

Against the backdrop of these developments, with the exception of Jorgenson *et al.* (2004b) and Gordon (2004), not much effort has been devoted to understanding what the post-2000 outlook looks like. This section tries to assess the robustness of the earlier evidence on Canada's aggregate multifactor productivity resurgence. Unfortunately, at this point, official US sources of GDP growth for the business sector are not available for recent years, which make a Canada-US comparison virtually impossible.

Within this context of slower economic growth and a modest contribution of capital and labour input, multifactor productivity gains in Canada remained almost the same as those posted by the economy in the late 1990s. The continuation during the 2000-2004 period of the rapid multifactor productivity gains that have started during the late 1990s tend to suggest that little of the late 1990s productivity performance upsurge was cyclical. The exploratory data developed by the BLS

Table 8. **Sources of real GDP growth of the business sector, Canada**
Average percentage point contribution

	1981-2000	1981-1988	1988-2000	1995-2000	2000-2004
Output growth	3.1	3.4	3.0	5.0	2.4
Contribution of capital services	1.5	1.5	1.5	2.0	0.6
Information technology	0.6	0.6	0.7	0.7	0.2
Non-information technology	1.0	1.1	0.9	1.4	0.4
Contribution of labour services	1.3	1.6	1.1	1.8	1.0
Multifactor productivity	0.4	0.3	0.4	1.2	0.8

show similar a similar sustainability of multifactor productivity performance for the US (see Meyer and Harper 2004).

CONCLUDING REMARKS

This paper extends, in many important respects, our earlier contribution on the extent to which information technology contributes to economic growth and productivity performance in both Canada and the United States. First, it uses an augmented aggregate growth accounting framework that identifies and quantifies all of the information technology channels that contribute to economic growth and productivity performance. Second, it develops a sectoral model fully integrated to the augmented aggregate growth accounting framework to trace the sectoral sources of the productivity revival.

The results of our examination are summarised as follows:

- The share of information technology output in Canada's business sector GDP has been rising fairly steadily, reaching 4.0% during the 1995-2000 period (6.1% for the US) compared with 2.7% during the 1981-1988 period (5.1% for the United States). The growth of information technology output has contributed about 19% of GDP growth in the second half of the 1990s, compared with 27.9% for the United States.
- On the input side, information technology experienced a similar pattern, but the differences between the two countries are more important. The share of information technology capital in Canada's business sector GDP has also been rising fairly steadily, reaching 8.3% during the 1995-2000 period (15.3% for the US) compared with 5.5% during the 1981-1988 period (8.9% for the United States). The growth of information technology input has contributed about 35.5% of overall capital services growth in the second half of the 1990s, compared with 60.4% for the United States.
- The adoption of information technology contributed modestly to Canada's productivity surge in the late 1990s. The contribution of information technol-

ogy to labour productivity growth has not been as strong in Canada as it has been in the United States.

- Contributions from information technology capital deepening are very similar in terms of timing (uplift from 1995) but not in magnitude between the early 1990s and the late 1990s (around 0.5 percentage point for the US, compared with 0.1 percentage point for Canada).
- During the late 1990s, information technology capital accounted for half of Canada's capital deepening growth (80% for the United States). Information technology capital deepening contributed 27.8% of labour productivity increase, up only slightly from 23.0% during the 1981-1988 period (respectively 37.0% and 26.3% for the United States).
- Canada has had a stronger contribution from multifactor productivity growth to the labour productivity revival between the early 1990s and the late 1990s (1.3 percentage points in Canada, 0.9 of a percentage point in the United States). The sectoral sources of multifactor productivity are another major important difference between Canada and the US: Canada's multifactor productivity revival in the late 1990s is almost entirely ascribed to information technology-using industries, while information technology-producing industries contributed two-thirds of the US productivity revival.

• Canada's stronger productivity growth means Canada benefited more from one or both of two factors:
  - greater productivity gains from information technology use, which would suggest that Canadian businesses were able to use information technology; and
  - greater productivity gains from non-information technology factors.

The coincidence of industries in Canada that are both relatively intensive information technology users and strong productivity performers provides some further evidence to link information technology with productivity growth.

Notes

1. The US studies restrict their analysis to information technology goods, covering the manufacture of computer hardware and software and communications equipment. The delivery of information technology services (for example, communications and Internet services) is excluded.
2. The wide variation in the findings across the different US studies is primarily attributable to the use of different data sources not reconciled one another. More on this in the next section.
3. See Harchaoui *et al.* (2004a) for an extension of this framework to include the services flow of consumer durables and housing.
4. There are three possible ways to treat these transactions. First, they could all be netted out, in which case we arrive at the notion of value added (or gross product originating for the United States). Secondly, the intra- and inter-sectoral transactions could be explicitly accounted for, in which case we arrive at the notion of gross output. Third, sectoral output, an intermediate notion between value added and gross output, nets out only intra-sectoral transactions.
5. See for example CEA (2001), Stiroh (2001), Jorgenson and Stiroh (2000) and Bosworth and Triplett (2004).
6. A recent work by Jorgenson *et al.* (2004a) uses a KLEMS database based on the notion gross output where information technology-producing industries are not mixed with electrical industries.
7. There is another set of industry data on gross output and employment, covering goods-producing and services-producing industries, produced by the BLS employment projections program from 1972 to recent years. This dataset has been used in Jorgenson *et al.* (2004b).
8. This dataset does not, however, provide a split of capital input between information technology and non-information technology.
9. This coverage is of course narrower than the one employed by Kask and Sieber (2002) in their profile of the US high tech manufacturing industries, but more consistent with the US literature on the role of information technology in the productivity revival.
10. The US BEA includes the statistical discrepancy in their estimate of "private industries", where the statistical discrepancy is defined as GDP expenditures less gross domestic income. Since the US BEA views the expenditure data as more reliable, the statistical discrepancy is added as an industry to the gross domestic income (value-added) accounts. One of the problems with the output of this industry is the impossibility to align it with measured inputs.
11. This paper differs in many respects from Harchaoui *et al.* (2004a). It covers the business sector and makes use of BLS data. In contrast, the latter covers the Canadian and US

private economies, which includes the business sector and owner-occupied housing. Another feature of the paper is the use of the flow of services of consumers' durables and housing 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.

12. This is the only period for which detailed industry data were comparable.
13. For more details, see Harchaoui and Tarkhani (2004b).
14. See Grimm *et al.* (2002) for details on the US methodology.
15. Eldridge and Sherwood (2001) have reached the same conclusion for the implicit price indexes of value added in two countries.
16. Both Statistics Canada and BLS capital input estimates for the business sector are based on the bottom-up approach. Alternatively, one could exploit a top-down approach which consists of using the investment series available from the final demand. The latter is more consistent with the production possibility frontier and it has been exploited in Harchaoui *et al.* (2004a). Comparability with the BLS' methods has prevented us from using this approach in this paper.
17. Owner-occupied housing is excluded for both countries.
18. Not taking worker characteristics into account has little effect on the estimates (See Gu *et al.* 2003).
19. Using the KLEMS data at two-digit industry detail available from the BLS, we reached similar results as the one obtained by the CEA (2001). This clearly highlights that regardless of the ways output is measured, the industrial composition has an important bearing on the estimates.
20. On the input side, the crucial share is:

$$\frac{u_{IT} K_{IT}}{pY}$$

On the output side, the crucial share is:

$$\frac{p_{IT} Y_{IT}}{pY} = \frac{p_{IT}}{u_{IT}} x \frac{Y_{IT}}{K_{IT}} x \frac{u_{IT} K_{IT}}{pY}$$

(Recall that u_{IT} is the rental price and p_{IT} is the price of information technology output Y_{IT}). Whether the shares indicated in the equations above rise or fall will be determined by the elasticity of substitution. If we hold the prices of all other inputs constant, we can aggregate them into a single input, say X. Then the elasticity of substitution is defined as:

$$\left(\frac{d \ln \frac{K_{IT}}{X}}{d \ln \frac{u_{IT}}{pX}} \right)$$

21. We assume a complete pass-through between the price change of sectoral intermediate inputs to sectoral output.

BIBLIOGRAPHY

Bailey, M.N. (2002), "The New Economy: Post Mortem or Second Wind", *Journal of Economic Perspectives*, 16 (2), pp. 3-22.

Council of Economic Advisors (CEA) (2001), *Economic Report of the President*, Washington, DC, US Government Printing Office.

Council of Economic Advisors (CEA) 2003, *Economic Report of the President*, Washington, DC, US Government Printing Office.

Domar, E.D. (1961), "On the Measurement of Technological Change", *Economic Journal*, LXXI (284), pp. 709-29.

Eldridge, L.P. and M.K. Sherwood (2001), "A Perspective on the US-Canada Manufacturing Productivity Gap", *Monthly Labor Review*, 124(2), pp. 31-48.

Gordon, R.J. (2000), "Does the 'New Economy' Measure Up to the Great Inventions of the Past?", *Journal of Economic Perspectives*, 14(4), pp. 49-74.

Gordon, R.J. (2004), "Five Puzzles in the Behavior of Productivity, Investment, and Innovation", NBER Working Paper No. w10660, August.

Grimm, B.T., B.R. Moulton and D.B. Wasshausen (2002), *Information Processing Equipment and Software in the National Accounts*, (pp. 36), Paper presented at the NBER/CRIW Meeting, Washington, April 2002.

Gu, W., M. Kaci, J.-P. Maynard and M. Sillamaa (2003), "The Changing Composition of the Canadian Workforce and Its Impact on Productivity Growth", in J.R. Baldwin and T.M. Harchaoui (eds), *Productivity Growth in Canada*. Statistics Canada, Catalogue No. 15-204, Ottawa: Statistics Canada.

Gullickson, W. and M. Harper (1999), "Possible Measurement Bias in Aggregate Productivity Growth", *Monthly Labor Review*, 122 (2), pp. 47-67.

Harchaoui, T.M., F. Tarkhani, C. Jackson and P. Armstrong (2002), "A Comparison of Canada-US Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communication Technologies", *Monthly Labor Review*, 125(10), pp. 3-12.

Harchaoui, T.M. and F. Tarkhani. (2003), "A Comprehensive Revision of the Capital Input Methodology for Statistics Canada Multifactor Productivity Program", in J.R. Baldwin and T.M. Harchaoui (eds.), *Productivity Growth in Canada* – 2002, Statistics Canada Catalogue No. 15-204-XIF. Ottawa: Statistics Canada.

Harchaoui, T.M., F. Tarkhani and B. Khanam. (2004a), "Information Technology and Economic Growth in the Canadian and US Private Economies", in *Economic Growth in Canada and the United States in the Information Age*. Edited by D. Jorgenson. Research Monograph, Ottawa: Industry Canada.

Harchaoui, T.M. and F. Tarkhani. (2004b), "Whatever Happened to Canada-US Economic Growth and Productivity Performance in the Information Age", *Economic Analysis Series No.* 25. Ottawa: Analytical Studies Branch, Statistics Canada.

Jorgenson, D.W., M.S. Ho and K.J. Stiroh (2004a), "Growth of US Industries and Investments in Information Technology and Higher Education", in C. Corrado, J. Haltiwanger and D. Sichel, (eds.), *Measurement of Capital in the New Economy*, Chicago, University of Chicago Press.

Jorgenson, D.W., M.S. Ho and K.J. Stiroh (2004b), "Will the US Productivity Resurgence Continue?", *Current Issues in Economics and Finance*, Volume 10, Number 13, December, Federal Reserve Bank of New York.

Jorgenson, D.W. (2001), "Information Technology and the US Economy", *American Economic Review*, 91(1), pp. 1-32.

Jorgenson, D.W. and K.J. Stiroh (2000), "Raising the Speed Limit: US Economic Growth in the Information Age", *Brookings Papers on Economic Activity*, Vol. 1, pp. 125-211.

Kask, K. and E. Sieber (2002), "Productivity Growth in 'High-Tech' Manufacturing Industries", *Monthly Labor Review*, March, pp. 17-31.

Meyer, P.B. and M.J. Harper (2004), "Research on Preliminary Estimates of Multifactor Productivity Growth", paper presented at the NBER Summer Institute, Boston.

Nordhaus, W. (2001), "Productivity Growth and the New Economy", NBER *Working Paper*, No. 8 096. Cambridge, MA.

OECD (2001), *The New Economy: Beyond the Hype: Final Report on the OECD Growth Project*, OECD, Paris.

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

Oliner, S.D. and D.E. Sichel (2002), "Information Technology and Productivity : Where are We Now and Where Are We Going?", Washington, DC, Board of Governors of the Federal Reserve.

Parham, D. (2002), "Productivity Growth in Australia: Are We Enjoying a Miracle?", paper presented at the Melbourne Institute/The Australian conference, *Towards Opportunity and Prosperity*, Melbourne, 4-5 April 2002.

Stiroh, K. (2001), "Information Technology and the US Productivity Revival: What Do the Industry Data Say?", Federal Reserve Board of New York (mimeo).

Tevlin, S. and K. Whelan (2000), "Explaining the Investment Boom of the 1990s", Washington, DC: Board of Governors of the Federal Reserve.

TABLE OF CONTENTS

This paper assesses the effect of strengthened intellectual property rights in developing countries on international licensing activity. The analysis draws on indicators for four dimensions of intellectual property right stringency (covering patent rights, copyrights and trademark rights, as well as enforcement effectiveness) and on firm-level data related to licensing. Overall, the analysis points to a net positive effect of IPR strength on licensing activity, an effect that is strongest with respect to the indicators for patent rights and effective enforcement. Where developing countries have moved to address weaknesses in these areas in recent years, they have tended to experience increased inward licensing of intellectual assets. The overall implication is that intellectual property rights can play an important role in enabling firms in developing nations to access and exploit technologies and know-how through licensing agreements with parties in developed nations.

Traditionally, immigrant stocks have been estimated by the foreign-born population in some countries and the foreign population in others. With the 2000 round of censuses, almost all OECD countries have identified the country of birth of enumerated persons. This allows for a more comprehensive and comparable portrayal of migration movements both within and to the OECD zone over recent decades, with a number of European countries showing immigrant numbers that are as large in relative terms as those observed for the United States. In addition, data on the educational attainment of the population permit, for the first time, direct estimation of the extent of expatriation of highly educated persons to OECD countries for over a hundred countries of origin across the globe. For a number of countries, more than half of all highly educated persons born there are living (and working) in OECD countries. Expatriation of the highly educated on this scale constitutes a significant drain on the human capital capabilities of these countries.

Using micro data for individual firms, this paper finds that non-financial corporations in Japan and the major European countries in 2003 were more vulnerable to a rise in short-term interest rates than they were in 1993 when the previous interest rate tightening cycle began (with a vulnerable firm being defined as one which has a high debt-to-equity ratio and a low ability to service the debt). In contrast firms in the United States and Canada appear more prepared for rising interest rates. Furthermore, looking only at data from 2003 the paper finds that firms in Japan and the major euro area countries are more vulnerable than firms in the United States, Canada and United Kingdom. The micro data are also used to create for each country an economy-wide measure of vulnerability, which turns out to be significantly related to future movements in GDP and investment growth.

From:
OECD Economic Studies

Access the journal at:
https://doi.org/10.1787/16097491

Please cite this article as:

Harchaoui, Tarek M. and Faouzi Tarkhani (2006), "Whatever happened to Canada-US economic growth and productivity performance in the information age?", *OECD Economic Studies*, Vol. 2005/1.

DOI: https://doi.org/10.1787/eco_studies-v2005-art6-en

OECD