Productivity Growth: Past Trends and Future Prospects in Canada

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Productivity is an important topic for discussion at this conference on global growth.[2] As a key determinant of increases in output and real income, higher productivity (output per person-hour) is an important source of improvements in the standard of living. Thus, a good understanding of the processes determining productivity will help us to assess the future prospects for increases in the standard of living.

A focus on productivity is also justified by the need to evaluate arguments that future rates of productivity growth will exceed those observed in recent decades. In large measure, this debate was spurred by the sharp increase in the growth rate of U.S. labour productivity in the second half of the 1990s.[3] Many analysts have asked whether this surge in productivity is likely to persist and spread to other countries. Interest in productivity issues has also intensified owing to the widespread belief that increased use of information and communication technology (ICT) will boost productivity growth in many sectors of the economy.

Finally, productivity is a relevant subject for this conference given empirical evidence that international linkages -- such as trade and investment flows -- can promote productivity growth. These linkages should be kept in mind when discussing the factors influencing future global growth.

In this paper, I describe the trends in productivity growth in Canada since the early 1960s and summarize our current knowledge about the causes of these historical patterns. Particular emphasis is given to the post-1995 period which corresponds to the period of rapid productivity gains in the United States. The paper also reviews evidence on the underlying determinants of productivity growth, and discusses whether the trend rate of productivity growth is likely to rise in Canada over the medium-term.

International comparisons of productivity growth are restricted to the Canada / U.S. case in this study. The focus on the United States is motivated by its position as Canada's major trading partner and the productivity leader in many sectors. In addition, Canadian data are probably more comparable with U.S. data than with those for many other countries. Although there is no formal discussion of productivity growth in the other G8 economies, the types of issues discussed in this paper will also be relevant when analyzing productivity developments in other countries.

1. Past Trends in Canadian Productivity Growth

The broad trends in labour productivity growth over the past four decades in Canada are now summarized and compared with the U.S. experience.

Aggregate business sector

The productivity performance of the Canadian business sector since the early 1960s can be separated into two distinct periods with the breakpoint in the mid-1970s (see Table 1 and Chart 1). Annual labour productivity growth averaged close to 4 per cent up to 1973 and then fell sharply to only 1.3 per cent for the 1974–95 period. Over the 1996–2001 period—the

1. The views in this paper are those of the author. No responsibility for them should be attributed to the Bank of Canada.

2. This paper was prepared for the conference on "Sustaining Global Growth: Prosperity, Security and Development Challenges for the Kananaskis G8", June 22, 2002. It draws heavily on a previous paper by the same author (Crawford 2002).

3. Unless otherwise indicated, the term "productivity" will be used to refer to labour productivity, defined as output per hour of labour input.

period of rapid productivity gains in the United States—the average growth rate increased modestly to 1.6 per cent in Canada.

Table 1

Labour-Productivity Growth

Average annual rates

	Canada		United States	
	Business sector	Manufacturing	Business sector	Manufacturing
1962–01	2.1	2.8	2.2	
1962–73	3.8	4.2	3.3	
1974–95[a]	1.3	2.4	1.5	2.9
1996–01	1.6		2.6	
1996–00[b]		0.9		4.9
1984–88	1.0	2.1	2.0	3.9

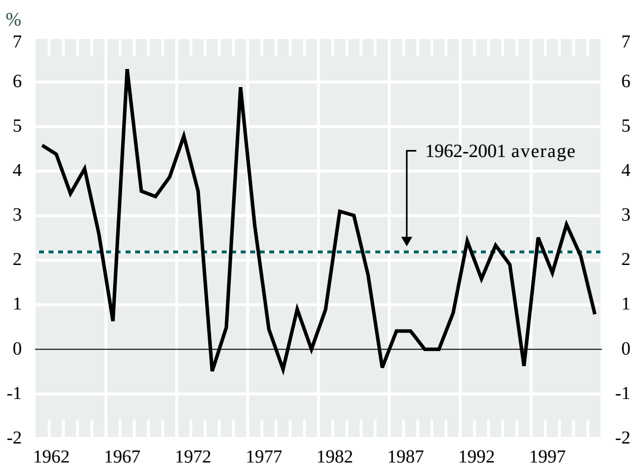
a. 1978–95 for U.S. manufacturing

b. Official productivity data for the manufacturing sector are currently available to 2000.

Chart 1

Labour Productivity Growth in Canada

Business sector



Increases in the productive capacity of an economy (potential output) depend on the underlying or *trend* rate of productivity growth. Therefore, there has been much interest in evaluating whether the observed growth in Canadian productivity in the late 1990s shows any signs of an increase in the trend rate of productivity growth. It is difficult to estimate the trend rate because year-to-year changes in productivity growth can be affected by cyclical movements in output. Since productivity growth tends to move procyclically,[4] some of the growth over this period could reflect the usual rebound during the recovery phase of the business cycle. It is therefore necessary to control for cyclical effects when estimating trend growth, and extreme caution must be used when drawing conclusions from short periods of time or from comparisons of periods spanning different stages of the cycle. It is interesting to note, however, that productivity growth in the Canadian business sector over the 1996–2001 period was somewhat stronger than over a similar stage of the previous cycle (1984 to 1988).

Sectoral patterns

The post-1973 slowdown occurred in both business-sector services and manufacturing in Canada. However, in recent years, these sectors have followed different paths. Productivity growth in the service sector strengthened in the second half of the 1990s relative to the 1989–95 period (Rao and Tang 2001). In contrast, following strong gains in the late 1980s and early 1990s, the average rate of labour-productivity growth in manufacturing fell to about 1 per cent in the 1996–2000 period (Table 1).

U.S. comparisons

A productivity slowdown also occurred in the U.S. business sector after the early 1970s as the average growth rate fell to 1.5 per cent from 1974 to 1995. Unlike the Canadian case, however, there was a significant pickup over the 1996–2001 period, with the average growth rate of labour productivity increasing to 2.6 per cent. This rebound pushed labour-productivity growth in the U.S. business sector one percentage point above the Canadian rate.

The recent pickup in U.S. productivity growth was broadly based across sectors. The difference between Canadian and U.S. performance since the mid-1990s has been particularly large in the manufacturing sector, where the average growth rate increased to almost 5 per cent in the United States. Higher rates were also observed in the U.S. service sector, most notably in wholesale and retail trade (Rao and Tang 2001).

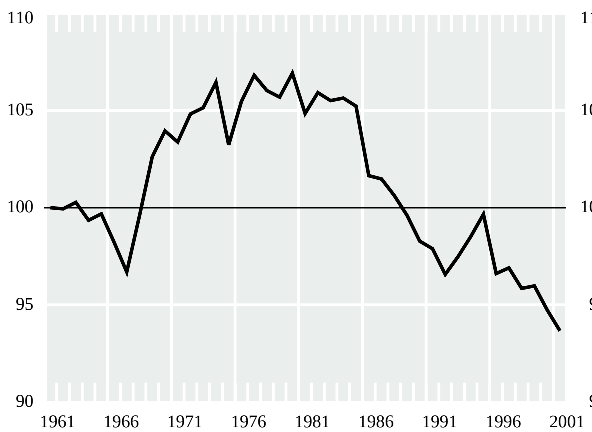
4. Because it is costly to adjust employment, labour input tends to fall less rapidly than output in the initial stages of a downturn. Thus, labour productivity growth tends to fall below its long-run trend at these times. Conversely, labour inputs may increase slowly as the economy starts to improve, so productivity growth tends to rise above its trend in the recovery stage of the cycle.

Simple growth models would predict that the diffusion of technologies and factor mobility would cause productivity levels in Canada to converge over time towards the higher levels in the United States. To provide some longer-run perspective on convergence, Chart 2 shows indexes of relative labour productivity in Canada, defined as the ratio of Canadian to U.S. productivity using an arbitrary base year indexed to 100.[5] Periods of convergence towards (divergence from) U.S. levels occur when the index of relative productivity in Chart 2 is rising (falling).

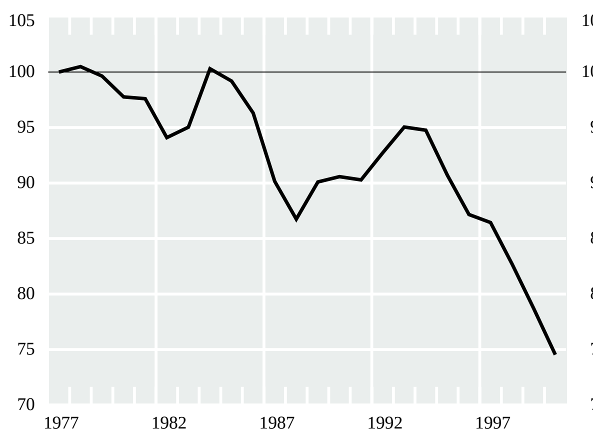
Chart 2

Relative Labour Productivity in Canada vs. the United States

Business sector (1961=100)



Manufacturing (1977=100)



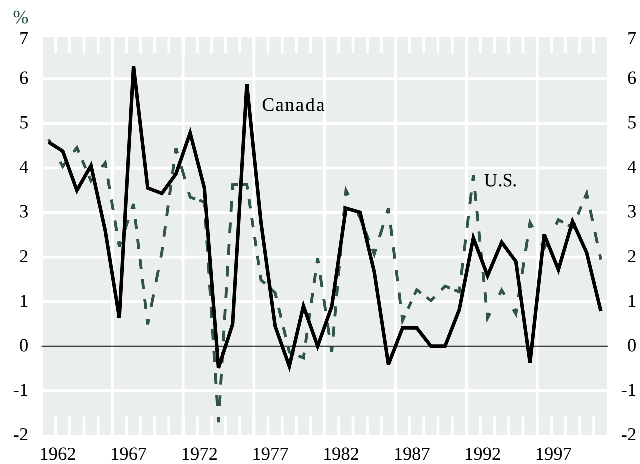
5. These indexes measure changes in relative productivity since the base year. Thus, the level of the index does not measure the absolute difference between the levels of productivity in the two countries.

There was some convergence of productivity in the Canadian business sector towards U.S. levels over the 1970s, but these gains have been more than reversed by the downward movements in the second half of the 1980s and the second half of the 1990s. Thus, while the late 1990s contributed to the decline in Canada's relative productivity, the beginning of the downward trend can be traced to an earlier date. The deterioration in relative performance in the late 1980s coincided with a period of very weak productivity growth in Canada's business sector, whereas the more recent deterioration reflects the increase in U.S. growth (Chart 3).

Chart 3

Labour Productivity Growth

Business sector



In the manufacturing sector, there was quite strong convergence towards U.S. productivity levels from the early 1960s until the mid-1970s.[6] Once again, this convergence has been more than reversed, with the index of relative productivity having fallen by approximately 25 per cent since the mid-1980s (bottom panel of Chart 2). Given the relatively weak productivity gains in Canadian manufacturing recently, Rao and Tang (2001) estimate that the absolute gap between the levels of labour productivity in

6. Because of data availability, comparisons of the Canadian and U.S. manufacturing sectors in the 1960s and early 1970s must use productivity data calculated from different measures of output. U.S. data for this period are based on a measure of gross output less intra-sectoral sales and transfers, whereas the Canadian data use real value-added. The graph for the manufacturing sector (Chart 2) covers the 1977–2000 period for which data are available for both countries on a value-added basis.

Canada and the United States had widened to 35 per cent in the manufacturing sector by 2000 (compared with 18 per cent for the economy-wide gap).

A comparison of Canadian and U.S. trends at a more disaggregated level shows which sectors contributed to the weaker growth in overall business-sector productivity in Canada in recent years.[7] In manufacturing, the large gap between Canadian and U.S. growth is explained largely by very rapid U.S. gains in the electrical / electronic equipment and other machinery and equipment sectors. In addition, Canada recorded weaker productivity growth in most of the major service-sector categories. Conversely, productivity growth was stronger in Canada than in the United States in primary industries and construction.[8]

In summary, Canada's relative productivity performance has deteriorated since the mid-1980s. Most recently, U.S. productivity growth has strengthened significantly since the mid-1990s, such that U.S. productivity has increased at rates significantly above those in Canada and in many other industrialized countries. Possible explanations for these trends are discussed in the following section.

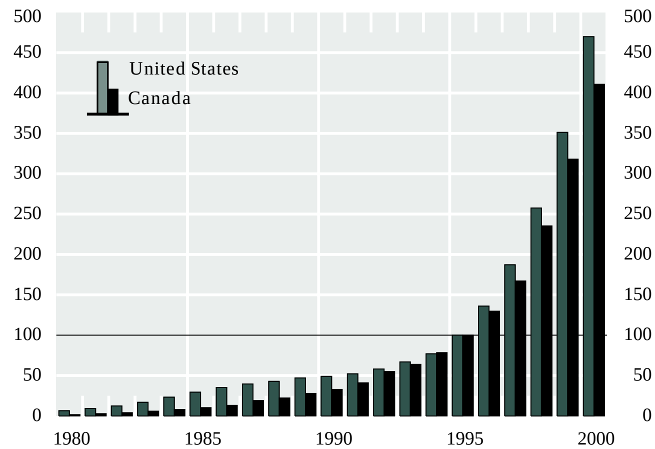
2. Sources of Recent Productivity Growth

Many observers have attributed a large part of the recent surge in U.S. productivity to efficiency gains from the production and use of information and communication technology (ICT). ICT is typically defined to include computer hardware, computer software, and telecommunications equipment. Driven by sharp declines in relative prices, the stocks of ICT capital, especially computer hardware, have increased at an extremely fast pace. From 1995 to 2000, the stock of computer hardware per person-hour in the U.S. business sector rose at an average annual rate of 36 per cent (Chart 4). Similar growth rates were observed in Canada over the same period.

Chart 4

Stock of Computer Hardware Per Person-Hour

1995=100



Source: Canadian data for computer hardware and person-hours are from Statistics Canada. U.S. data are from the Bureau of Economic Analysis and the Bureau of Labor Statistics.

The hypothesized link between ICT investment and productivity growth is consistent with the view that ICT is a "general-purpose technology" with productivity-enhancing applications in many sectors of the economy. To give just a few examples, ICT may raise productivity by providing: more efficient means of processing and delivering information; better systems for managing product distribution and inventories; and more efficient methods of designing and producing manufactured goods.

Several studies have estimated the impact of information technology and other influences on labour-productivity growth using the "growth-accounting" methodology. As described in Box 1, this technique uses the characteristics of a production function to decompose the observed data for labour-productivity growth into estimates of the contributions from each of the following channels: (i) changes in the capital-labour ratio for ICT capital goods ("ICT capital deepening"); (ii) changes in the capital-labour ratio for non-ICT capital ("non-ICT capital deepening"); (iii) changes in labour quality; and (iv) changes in multifactor productivity (MFP). Changes in MFP represent the change in output from sources other than changes in inputs and labour quality.[9]

In empirical studies, the total effect of ICT on labour productivity is calculated as the sum of the contributions from the *use* of ICT goods by firms plus

7. This paragraph is based on analysis of the 1995-99 period by Rao and Tang (2001).

8. In 1999, Canadian *levels* of labour productivity exceeded those in the United States in only a few industries (primarily resource-based industries and transportation equipment) and were substantially lower in the electrical / electronic equipment and other machinery and equipment sectors (Government of Canada 2002a).

Box 1: Measuring the Sources of Productivity Growth

Labour productivity is the amount of output produced per hour of labour input. It depends on a number of factors, including the current state of technology and the quantities of other inputs used in the production process.

The link between investment in capital goods and productivity is critical when analyzing the sources of labour-productivity growth. To illustrate this relationship, consider a simple Cobb-Douglas production technology in which real output Y is produced using capital and labour inputs:

$$Y = AK^{\alpha_K} L^{\alpha_L} , \quad (1)$$

where K is the quantity of capital, L is hours of labour input, and A is multifactor productivity. The exponent α_K is interpreted as the percentage change in output resulting from a 1 per cent change in the quantity of capital (holding technology and the amount of labour unchanged). The exponent α_L has a similar interpretation as the percentage change in output following a 1 per cent change in labour input. Changes in multifactor productivity measure the change in output from sources other than changes in capital and labour inputs (e.g. improved efficiency of production resulting from technological innovations or the introduction of new business and organizational practices).

With perfect competition and constant returns to scale, the sum of the α exponents equals one, and α_K and α_L are measured by the shares of aggregate income earned by capital and labour, respectively. In this case, the level of labour productivity is determined by multifactor productivity and the *ratio* of capital to labour in the following manner:

$$Y/L = A(K/L)^{\alpha_K} . \quad (2)$$

Thus, labour-productivity growth can be decomposed into the contributions from the change in multifactor productivity and the change in the capital-to-labour ratio (capital deepening).[1] An increase in the amount of capital available per person-hour will raise labour productivity.

In empirical studies, the contribution of information and communication technology (ICT) to labour-productivity growth is estimated using modified versions of the framework just described. In these studies, equations (1) and (2) are extended to include different types of capital goods (e.g., ICT versus non-ICT capital). The total effect of ICT on labour productivity is measured as the sum of the contribution to productivity growth from the *use* of ICT goods (by firms in all sectors) and the contribution from the sectors that *produce* ICT goods. The contribution from capital deepening by users of ICT is estimated by the product of the income share of ICT and the growth rate of ICT capital per person-hour. The contribution from multifactor productivity (MFP) growth in ICT-producing sectors is included in the term for the growth rate of aggregate MFP.

1. Specifically, equation (2) implies that the growth rate of labour productivity is equal to the growth rate of multifactor productivity plus the income share of capital (α_K) multiplied by the growth rate of capital per person-hour. Although not included in the simple model described in this box, changes in the average quality of labour would also affect the growth of labour productivity.

the contributions from the sectors that *produce* ICT goods. The former is measured by the capital deepening (or first) channel in the above list. The additional contribution from more efficient production by ICT producers is included in the term for aggregate multifactor productivity growth. Empirical results from U.S. and Canadian studies of this type are presented below.

U.S. studies

Jorgenson, Ho, and Stiroh (2001) applied the growth-accounting methodology to U.S. data for the private sector.[10,11] Their results suggest that ICT was the dominant factor underlying the recent improvement in the growth of U.S. labour productivity. Over the 1995–2000 period, the total contribution from ICT use by firms and MFP gains in ICT-producing sectors rose to 1.27 percentage points (Table 2). Greater ICT use explained almost 50 per cent of the 0.92 percentage-point *increase* in labour-productivity growth over this period, while ICT production contributed another 30 per cent.[12]

Gordon (2000) went a step further by separating the observed increase in U.S. productivity growth over the 1995-1999 period into estimates of the increase in trend productivity growth and the cyclical effect. If we abstract from the effect of improvements in methods used to construct the official U.S. data, his estimates imply that the increase in trend labour-productivity growth was 0.69 percentage points. Most of this gain (0.62 percentage points) was attributed to ICT capital deepening and faster MFP growth in the computer-producing sectors.

Table 2

Sources of Labour-Productivity Growth

U.S. private sector

	1959–73	1973–95	1995–00	Change: 1973–95 to 1995–00
Labour-productivity growth[a]	2.97	1.44	2.36	0.92
Contributions from[b]:				
ICT capital deepening	0.16	0.32	0.76	0.44
MFP growth in ICT-producing sectors	0.10	0.24	0.51	0.27
Other[c]	2.71	0.88	1.09	0.21
Total contribution from ICT (capital deepening + MFP growth in ICT-producing sectors)	0.26	0.56	1.27	0.71

a. Average annual growth rate

b. Percentage points per year

c. Includes non-ICT capital deepening, labour quality, and MFP growth at non-ICT producers

Source: Jorgenson, Ho, and Stiroh (2001)

The growth-accounting exercises are mechanical decompositions conducted at the level of aggregate business sector output. If ICT has an important effect on productivity, there should be corroborating evidence at a more disaggregated level. That is, after controlling for other factors, the firms or industries that use ICT most intensively should display significantly better productivity performance. Disaggregated econometric analysis has been done in a number of U.S. studies, including Stiroh (2001) who uses data for a broad cross-section of approximately 60 sectors, and Brynjolfsson and Hitt (1995, 1998, 2000a, and 2000b) who use micro-data for individual firms. Overall, their results confirm that ICT use is an important determinant of productivity.

Stiroh (2001) also examines the importance of ICT by breaking down the change in aggregate labour productivity into the contributions from three sets of industries: intensive ICT users, ICT-producing sectors, and the remaining sectors. This breakdown suggests that almost all of the increase in U.S. productivity growth can be traced to sectors that either produce or use ICT intensively.[13] Since the gains were broadly based throughout the ICT-intensive sectors and were not found in the less-ICT-intensive sectors, he rejects the view that the cyclical recovery and ICT production were the dominant sources of the surge in U.S. productivity. The significant role for structural factors is

9. While informative, the growth-accounting calculations do not explain the underlying determinants of capital investment, changes in labour quality, or MFP growth. Some discussion of the underlying determinants is provided in section 3.

10. Jorgenson, Ho, and Stiroh’s measure of output is broader in coverage than the measure used to construct the official U.S. productivity data reported in Table 1. Their output series includes the non-profit sector and imputed capital service flows from residential housing and consumer durables. Evidence from other studies indicates that use of the broader output measure will tend to reduce the estimated ICT contribution by a small amount.

11. Jorgenson, Ho, and Stiroh use data for the *flow* of capital services, which are calculated by multiplying rental prices by the effective capital stocks. The Canadian study by Armstrong et al. (2002), discussed below, also uses a measure of the flow of capital services.

12. Oliner and Sichel (2000) reached similar conclusions about the contribution of ICT in the second half of the 1990s. In contrast to the study by Jorgenson, Ho, and Stiroh, their study (and Gordon 2000) used the official productivity statistics.

13. Similarly, Sharpe (2000) argues that the increases in productivity growth in the U.S. service sector (particularly wholesale and retail trade) can be attributed to high levels of ICT investment in these sectors. Also, Sieling, Friedman and Dumas (2001) conclude that increased use of technologies contributed to the stronger productivity gains in the U.S. retail industry.

consistent with the fact that the productivity spurt occurred relatively late in the U.S. economic expansion (a time when productivity growth typically weakens).

Canadian studies

Armstrong, Harchaoui, Jackson, and Tarkhani (2002) analyzed the individual sources of labour-productivity growth in Canada. Their calculations suggest that ICT use contributed 0.4 percentage points to average productivity growth in the second half of the 1990s (Table 3). Unlike the U.S. results reported earlier, there was no increase (relative to 1988–95) in the effect of ICT capital deepening over this period.[14] For the other sources of labour-productivity growth, they report a sharp increase in MFP growth and lower contributions from non-ICT capital and labour quality.

Armstrong et al. do not estimate the contribution of the ICT-producing sector to MFP growth in Canada. For comparison with U.S. results, a rough measure of the total ICT contribution is obtained by combining their estimate of the capital-deepening effect and the estimated MFP effect found by Muir and Robidoux (2001). The estimated total ICT contribution over the past five years in Canada (0.6 percentage points) is approximately half of the U.S. level during the same period, with no increase relative to 1988–95. Thus, the growth-accounting studies imply that differences related to the use and production of ICT account for most of the recent divergence in labour-productivity growth between Canada and the United States.

The lower ICT effect in Canada reflects smaller estimates of the gains from both ICT use and ICT production. Table 4 presents information to explain these results. As noted in Box 1, the estimated effect from ICT use is calculated as the product of the growth rate of ICT capital per person-hour and the ICT income share. The smaller contribution from ICT use largely reflects the lower estimate of the income share for ICT capital in Canada. There is a smaller effect from ICT production for two reasons. First, the industries producing ICT goods account for a smaller share of Canadian output. In addition, productivity growth in the ICT-producing sector is considerably lower in Canada than in the United States. From 1995 to 2000, output per worker in ICT manufacturing increased at an average annual rate of about 14 per cent in Canada, compared with 43 per cent in the United States (Rao and Tang 2001).[15] Some of this gap in productivity growth reflects differences in the mix of goods produced by the ICT sectors in the two countries (e.g., whereas the U.S. manufactures computer chips—an industry with high rates of productivity growth—Canada does not produce these goods).

Table 3

Sources of Labour-Productivity Growth

Canadian business sector

	1981–88	1988–95	1995–00
Labour-productivity growth[a]	1.3	1.2	1.7
Contributions from[b]:			
(i) Capital deepening	0.6	0.9	0.4
ICT	0.3	0.4	0.4
Non-ICT	0.2	0.4	0.0
(ii) Labour quality	0.5	0.6	0.3
(iii) MFP growth		-0.3	1.0
(from ICT producers)[c]	0.3	(0.2)	(0.2)
Total contribution from ICT (capital deepening + MFP of ICT producers)		0.6	0.6

a. Average annual growth rate
b. Percentage points per year
c. From Table 3 in Muir and Robidoux (2001). Their estimates cover the periods 1991–95 and 1996–00.
Source: Armstrong et al. (2002).

Table 4

ICT Use and Production

	ICT use (1996-00)				ICT production[a]
	ICT income share[b] (percentage points)	Average growth rate per person-hour			Share of ICT goods in business sector value-added (1998)
		Hardware[c]	Software	Communication equipment	
Canada	2.87	32.7	11.7	5.0	1.81
United States	6.3	36.3	13.0	7.4	2.56

a. From Annex Table 2 of Pilat and Lee (2001). The definition of ICT goods includes such categories as office and computing machinery, electronic equipment, and industrial-process-control equipment.
b. Jorgenson, Ho, and Stiroh (2001) and Armstrong et al. (2002) do not report the income shares of ICT capital in their studies. The U.S. income shares shown in this table are from Oliner and Sichel (2000) and the Canadian shares are from Khan and Santos (2002). The U.S. shares cover the period 1996–99.
c: The table reports growth rates of capital stocks per person-hour. Jorgenson, Ho, and Stiroh (2001) and Armstrong et al. (2002) use growth rates of the flow of capital services per person-hour.

14. Khan and Santos (2002) reach conclusions similar to those of Armstrong et al. (2002) regarding the effects of ICT use.

15. Note that these figures are growth rates of labour productivity in ICT manufacturing, whereas the estimated contributions from ICT production in Tables 2 and 3 are contributions to MFP growth.

Baldwin and Sabourin (2002) provide micro-econometric confirmation that ICT investment significantly affects productivity in the Canadian manufacturing sector. Using micro data for individual plants, they find a positive relationship between the use of computer-based technologies in 1998 and the cumulative growth in relative labour productivity over the 1988–97 period (compared with other plants in the same narrowly defined industry). The relationship between productivity gains and ICT use was particularly strong for plants that had adopted applications from all three of the major categories of ICT technologies (software, hardware, and network communications).

3. Outlook for Future Productivity Growth

As noted earlier, the *trend* rate of productivity growth is a key determinant of the rate of increase in the productive capacity of an economy (potential output). Thus, knowledge of the future prospects for the trend rate of productivity growth is useful for evaluating the outlook for future increases in output, real incomes, and the standard of living.

Before proceeding, it is important to acknowledge the inherent uncertainties when forecasting future trends in productivity. Current rates of productivity growth are affected by the stage of the business cycle, so it may be difficult to identify the underlying trend. There is also uncertainty about the future impact of "general purpose technologies" such as ICT on average rates of productivity growth over long periods, as well as the timing of these effects. The productivity gains can spread over decades, depending on how the technology evolves and organizational and institutional structures adjust to the new conditions (see Lipsey 2002).

The growth-accounting framework in section 2 implies that the rate of labour-productivity growth depends on the rates of change in capital intensity, multifactor productivity, and labour quality. Accordingly, forming a view on the future levels of these three variables would yield a forecast for the future path of labour-productivity growth. But what are the critical factors determining these variables?

Some guidance on this question can be obtained from the cross-country growth literature. In these studies, time-series data from a number of countries are used to determine how growth rates of real output per capita are affected by changes in inputs (physical and human capital), structural government policies, and institutional conditions such as the development of financial markets.[16] Based on his assessment of the cross-country literature, Harris (1999) concludes that the three most important factors affecting growth are investment in machinery and equipment, improvements in human capital (skills), and openness to trade and investment. In various ways, each of these factors strengthens productivity growth by promoting innovation and the diffusion and effective use of new technologies. Other authors have emphasized the roles of business and organizational practices, structural and regulatory policies, and research and development.

In order to assess the future outlook for trend productivity growth in Canada, some Canadian developments in these areas are reviewed briefly below. Although each of the channels will be discussed individually, in many cases they interact with each other to affect productivity.

3.1 Investment in machinery and equipment

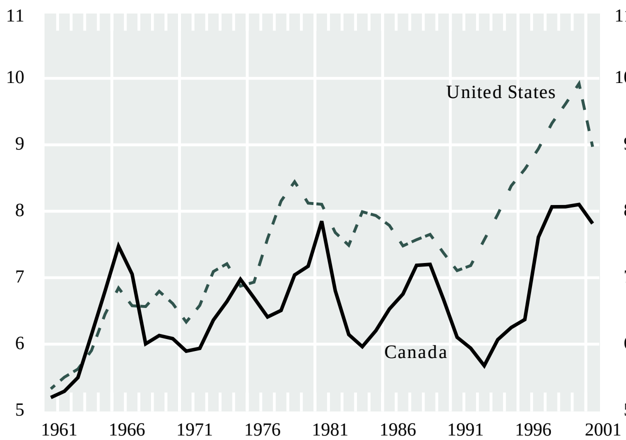
The ratio of business investment in machinery and equipment (M & E) to GDP tends to be an important determinant of productivity growth in the cross-country studies. One reason for this finding is that new capital goods incorporate productivity-enhancing technological progress. On average, the ratio of M & E to GDP was virtually identical in Canada and the United States during the 1960s (Chart 5). More recently, the decade averages have trended upwards in the United States but have remained relatively unchanged in Canada, with the result that the average ratio in the 1990s was about 1.5 percentage points lower in Canada. The evidence from cross-country growth studies suggests that the growing gap in this ratio may have contributed to the deterioration in Canada's relative productivity performance.

High levels of spending on machinery and equipment (including ICT goods) led to a sharp increase in the U.S. ratio beginning in 1993. The lag between the start of the acceleration in the pace of investment spending in the early 1990s and the surge

16. For example, policy and institutional variables in the recent study of OECD countries by Bassanini, Scarpetta, and Hemmings (2001) include measures of inflation (level and variability), fiscal variables (tax rates and expenditures), R & D intensity, measures of financial development (business credit and stock market capitalization), and exposure to international trade.

Chart 5

Business Investment in Machinery and Equipment as a Share of Nominal GDP (%)



ferences suggest that productivity growth may increase less than in the United States.

in U.S. productivity growth later in the decade is consistent with the view that some of the productivity payoffs from investments are not realized immediately.[17] The Canadian investment ratio did not rise above the level of the late 1980s until 1997, four years after the pickup in the United States. If the timing hypothesis is correct, these high levels of investment should raise trend productivity growth in Canada over the next few years (Macklem and Yetman 2001). Despite the recent increases, however, the ratio of investment in machinery and equipment to GDP in 2001 was about 1 percentage point lower in Canada than in the United States.

Looking ahead, there is some evidence that average firm size is one factor that may affect the future rates of technology adoption and innovation in Canada. Small- and medium-sized firms in manufacturing have been slower than larger firms to adopt new advanced technologies.[18] Adoption rates in these size categories are lower in Canada than in the United States (Baldwin and Sabourin 1998), and small firms account for a larger share of manufacturing output in Canada (Baldwin, Jarmin, and Tang 2002). These differences suggest that productivity growth may increase less than in the United States.

3.2 Business and organizational practices

Another determinant of future productivity growth will be the ability of firms to introduce better business and organizational practices into the workplace. In 1998-2000, approximately 40 per cent of Canadian firms implemented improved organizational structures or management techniques (Earl 2002). One reason for such changes is that practices that were appropriate for older technologies may no longer be optimal under new conditions.

David (1990) and Lipsey (1996) discuss the interesting historical example of the replacement of steam power by electricity. With steam-power technology, machinery was operated most efficiently in factories with two stories. With the introduction of electricity, it became more efficient to build factories with one floor and arrange machinery in the same sequence as the flow of production. This restructuring process was spread over decades, as firms needed to recognize the opportunities and implement fundamental changes in the layout of buildings. Over time, however, considerable improvements in productivity were achieved as business practices adjusted to the new technology.

A similar phenomenon may help to explain the empirical evidence of long lags between the timing of ICT investments and their full impact on productivity. Using data for large U.S. firms, Brynjolfsson and Hitt (2000a) estimate that the returns from ICT investment are two to five times greater over periods of 5 to 7 years than over a 1-year period. The long lags may arise because firms must fundamentally alter their business practices in order to fully exploit the advantages of new ICT technologies.[19] It may take time for firms to learn what changes are needed to make effective use of these technologies, and delays may also occur because the adjustments are costly and time-consuming. As a result, the productivity gains from information and computer technologies will rise over

17. This view is discussed further in section 3.2 below.

18. In 1998, large firms in the Canadian manufacturing sector were more than twice as likely to use advanced technologies as smaller firms (Baldwin and Sabourin 2000). Similarly, evidence from Statistics Canada's 1999 Survey of Innovation indicates that smaller firms in the manufacturing sector were less inclined to implement new or improved production processes over the 1997-99 period (Rao, Tang and Wang 2002).

19. As noted by Brynjolfsson and Hitt (2000b):

"Most of our economic institutions and intuitions emerged in an era of relatively high communications costs and limited computational capability (p. 24) ... as the cost of automated information processing has fallen by over 99.9 per cent since the 1960s, it is unlikely that the work practices of the previous era will be the same ones that best leverage the value of cheap information and flexible production ..." (p. 26).

time as firms are gradually able to implement these changes.

Schaan and Anderson (2001) report survey evidence of these types of adjustment problems in Canada. Approximately 90 per cent of manufacturing firms that innovated (defined as having introduced new production processes or developed new products) during the 1997-99 period experienced difficulties that "slowed down or caused problems." The most common problems were an inability to devote staff to projects because of current production requirements, high costs of development, and lack of skilled personnel. Econometric support for the complementarity of ICT and organizational changes is provided by Brynjolfsson and Hitt (1998), who find that ICT has a greater effect on productivity when firms adopt more decentralized decision-making processes.

3.3 Investment in human capital (skills)

The average level of human capital increases when there is an improvement in the average skill level of workers. Human capital contributes to productivity growth by enabling firms to develop new technologies or capture the full benefits when adopting technologies developed elsewhere. Investment in human capital can take the form of increased quantity of education (e.g., average years of schooling), increased quality of education, or on-the-job training. Hanuschek and Kimko (2000) and Barro (2001) report cross-country evidence that the *quality* of schooling, as proxied by student scores on standardized international exams in sciences, has a stronger effect on growth than the quantity of schooling.

Historically, the average number of years of formal education has been very similar in Canada and the United States: in 1998, this measure was 12.9 in Canada and 12.7 in the United States, compared with the OECD average of 11.3 (Bassanini, Scarpetta, and Hemmings 2001). As shown in Chart 6, close to 40 per cent of Canadians aged 25 to 64 have completed some form of post-secondary education, which is the highest proportion among OECD countries. There are some compositional differences relative to the United States, as a higher percentage of Canadians have a non-university (college) post-secondary education, and a lower percentage have a university degree. In recent years, the average educational attainment of employed Canadians has risen steadily (Chart 7).

Chart 6

Percentage of the Population Aged 25 to 64 with Completed Post-Secondary Education, 1999

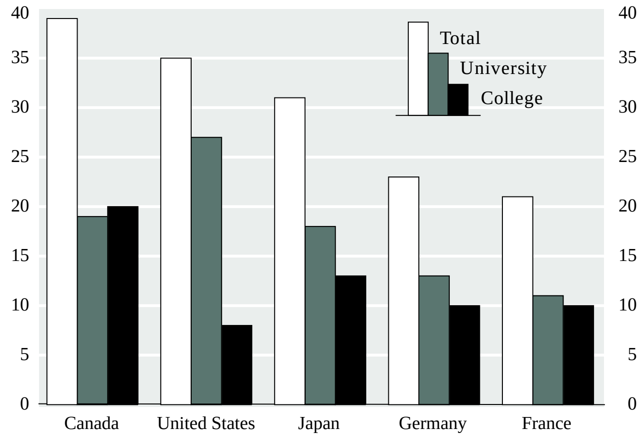
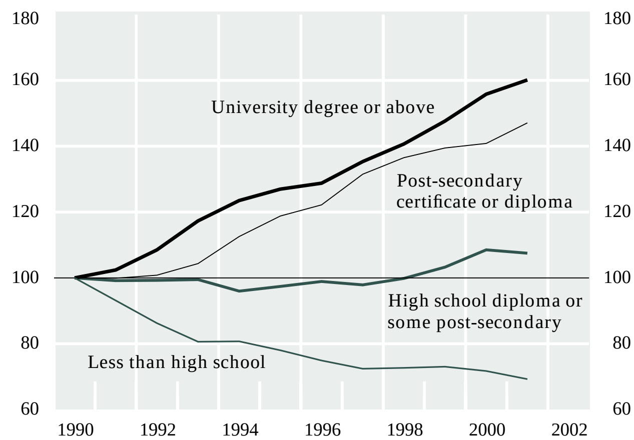


Chart 7

Employment by Education Attainment in Canada

Indexed to 1990=100



Rodriguez and Sargent (2001) compare alternative measures of human capital for Canada and the United States, including the proportion of the population with higher education and indexes that take into account changes in the average quality of labour. On balance, they conclude that the current levels (and recent rates of change) of human capital per worker are similar in the two countries. Additional evidence on the quality of human capital is provided by a recent OECD study, which reports that 15-year-old

Canadian students outperformed their U.S. counterparts and the OECD average in international exams on reading, mathematics, and science (Sweetman 2002).

While there are encouraging signs, there are also challenges that could affect the pace of future productivity growth:[20] (i) shortages of skilled workers are reported in some specialized areas, and there is strong international competition for people with these skills, (ii) relative to the United States, Canada has a lower proportion of people with advanced research degrees, and (iii) employer-sponsored training is less prevalent in Canada than in the United States.

3.4 Openness to trade and investment

Cross-country growth studies proxy the degree of openness using measures of international trade flows and foreign direct investment. Openness may contribute to productivity growth by facilitating the diffusion of technologies. Low trade and regulatory barriers may also promote more efficient allocation of resources and the achievement of economies of scale in production.[21] Canada is heavily dependent on international trade, with the ratios of exports and imports to GDP equal to approximately 40 per cent and 35 per cent, respectively.

Several pieces of Canadian evidence are consistent with the hypothesis that openness contributes to growth. First, Trefler (1999) finds that tariff reductions under the Canada-U.S. Free Trade Agreement increased labour-productivity growth in the manufacturing sector over the 1989–96 period. Second, productivity growth has been stronger at foreign-controlled establishments in the manufacturing sector, and these establishments are more likely to adopt computer-based technologies than domestically-controlled companies (Baldwin and Dhaliwal 2001). Other evidence of openness effects is provided by Gera, Gu, and Lee (1999). Using industry-level data, they show that spillovers from foreign research and development (R & D) spending (embodied in purchases of imported intermediate goods and services) are a significant determinant of labour-productivity growth in Canada.[22] These R & D spillover effects are particularly important in the case of imported information technology goods.

The intensity of domestic R & D spending is a significant determinant of productivity growth in the empirical literature. To some extent, the spillover effects from foreign R & D offset the impact of low domestic R & D spending in Canada. In 1997, Canada had the second lowest ratio of domestic R & D spending to GDP among the G-7 countries, although this gap has closed somewhat since 1990 (Rao et al. 2001).

3.5 Structural and regulatory policies

The overall growth in economy-wide productivity reflects changes in productivity within firms as well as a compositional effect from the reallocation of resources across firms and different industries. For example, a shift in resources from less-productive to more-productive firms will raise the average level of productivity in that industry. Consequently, structural and regulatory policies that affect innovative activity, the entry / exit decisions of firms, and factor mobility will have an impact on aggregate productivity growth.[23]

Researchers who have examined productivity using micro data for individual firms or establishments find that there is: (i) considerable heterogeneity of levels and growth rates of productivity across firms in the same sector; and (ii) extensive reallocation of output and inputs among firms *within* sectors (encompassing both expansions and contractions of existing firms as well as the entries and exits of firms). Both of these stylized facts are evident in the Canadian manufacturing sector: (i) small plants have lower levels and growth rates of productivity than larger plants (Baldwin and Dhaliwal 2001; Baldwin, Jarmin, and Tang 2002); and (ii) 47 per cent of market share was transferred from losers to gainers of market share between 1988 and 1997, with the relative productivity of gainers rising by 23 per cent (Baldwin and Sabourin 2002).

20. These issues are discussed in Government of Canada (2002b).

21. Alcala and Ciccone (2001) estimate the effects of international trade on labour productivity using data for a large number of countries.

22. For the most recent period in their study (1990–93), the R & D embodied in imports accounted for approximately 65 per cent of the total R & D intensity in the Canadian business sector (defined as the industry's own R & D spending plus the R & D embodied in purchases of domestic and foreign goods and services).

23. See OECD (2002) for a discussion of the effects on productivity of certain types of regulations.

These results imply that a significant share of aggregate productivity growth can be attributed to resource reallocations across different firms in the same industry.

3.6 Summary

A critical issue for the future is whether the recent surge in U.S. productivity growth will be replicated in Canada. The preceding analysis is now used to assess this question.

There are some positive signs suggesting that the future level of trend productivity growth in Canada will exceed the historical average from the post-1973 era.

- Investment in machinery and equipment increased as a share of GDP over the 1990s. Given the lags between the timing of investment and the realization of productivity gains, this increased investment should support higher trend productivity growth, at least over the very near term. If the ratio of M & E to GDP is sustained at the higher level, a more persistent period of higher trend growth would be expected.
- Increased ICT use was a major source of the acceleration in the rate of U.S. productivity growth. With further declines in the relative price of ICT goods, continued diffusion of these technologies in Canada should support future productivity growth in many sectors.
- Canada has a high exposure to international trade and investment. Empirical evidence indicates that this openness promotes the diffusion of knowledge and new technologies.
- Canada's macropolicy framework of low (and stable) inflation and improved fiscal positions provides a good supporting environment for efficient decision-making by firms.
- U.S. productivity growth was surprisingly strong through 2001 despite the cyclical downturn in the U.S. economy.[24] This suggests that a significant part of the surge in U.S. growth will be sustained. To the extent that the underlying factors (such as ICT) are common to Canada and the United States, there is reason to expect stronger trend growth in Canada.

Reasons for a more cautious perspective on future trend productivity growth (relative to the United States) include the following points.

- ICT-producing industries, which have made major contributions to the high productivity growth in the U.S. manufacturing sector, account for a smaller share of Canadian output. Moreover, although productivity gains in ICT production have also been strong in Canada, they have been significantly lower than in the United States. Some of this difference in growth rates reflects structural differences in the composition of ICT output.
- Canadian firms appear to be slower to adopt new technologies.
- Canada has a relatively low rate of domestic R & D spending.

One characteristic of a "general-purpose technology" such as ICT is considerable uncertainty about the long-run consequences for trend productivity growth and the timing of these effects. This makes it difficult to forecast the trends in productivity growth over the next decade. While recognizing this uncertainty, on balance, it seems reasonable to anticipate some increase in trend productivity growth in Canada relative to the levels observed since the mid-1970s.

24. In the fourth quarter of 2001, productivity in the U.S. business sector was 2 per cent higher than four quarters previously, while business sector output was unchanged.

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