Trends in Productivity Growth in Canada

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- *The rate of productivity growth in the United States was significantly higher than that in Canada during the second half of the 1990s.*
- *Much of the difference between Canadian and U.S. rates of productivity growth over this period was related to information and communication technology (ICT), with firms in the United States making greater productivity gains from the use of ICT. Productivity growth in the sectors producing ICT goods was also significantly higher in the United States.*
- *International evidence indicates that a variety of other factors, including investment in human capital and openness to international trade, influence a country's productivity performance. High exposure to international trade has made a positive contribution to productivity growth in Canada.*
- *Whether the recent surge in U.S. productivity will be replicated in Canada is a critical issue for the future. While there is uncertainty about future rates of Canadian productivity growth, it is reasonable to expect some increase in trend growth relative to the rates of recent decades.*

Recent developments have focused attention on the possibility that future rates of productivity growth will rise above those observed in recent decades. In large measure, this interest was spurred by a sharp increase in the growth rate of U.S. labour productivity in the second half of the 1990s.[1] Observers in many countries have asked whether this surge in productivity is likely to spread to other economies. Interest in productivity issues has also risen in recent years owing to expectations that increased use of information and communication technology (ICT) will boost productivity growth in many sectors of the economy.

A good understanding of the determinants of productivity is important because productivity has far-reaching implications for the economy. For example, Rao (2001) estimates that lower levels of productivity in Canada accounted for over 80 per cent of the average gap in real GDP per capita between Canada and the United States in the 1990s.[2] Thus, closing the productivity gap would be a crucial element in reducing the gap in the standard of living between the two countries.

Productivity growth is also an important variable in the decision-making process for monetary policy. When implementing a policy of inflation control, the monetary authorities must consider future inflationary pressures as measured by the level of output relative to the economy's capacity for sustainable production (potential output).[3] Since potential output

1. Unless otherwise indicated, in this article the term "productivity" refers to labour productivity, defined as output per person-hour. See Box 1 for further discussion of measurement issues.

2. The remainder of the gap in real GDP per capita is attributed to lower hours worked per capita in Canada.

3. Inflation will tend to increase (decrease) if actual output is greater (less) than potential output.

Box 1: Measurement Issues

There are long-standing concerns that official statistics understate the true rate of productivity growth, because of measurement problems. Two of the most prominent concerns are: (i) aggregate productivity will be understated if the price deflators used to calculate real output do not fully capture improvements in product quality; and (ii) output (and therefore productivity) is particularly difficult to measure in many of the service sectors.

Deflators and Quality Adjustments

Real output and productivity will be measured incorrectly if the price indexes used as deflators are not adjusted to eliminate the influence of changes in quality on observed prices. Statistical agencies use various techniques to construct quality-adjusted measures of price change. Biases are introduced, however, if the correct quality adjustments are not made, and this task may be especially difficult for durable goods in times of rapid technological change.

In some cases, biased deflators may have a greater effect on the allocation of measured productivity growth across sectors than on the aggregate measure of productivity. This can be illustrated by noting that Statistics Canada uses the "double deflation" method to construct real output (value-added). In this technique, nominal levels of gross output and intermediate inputs are deflated separately, and then the real value of intermediate inputs is subtracted from real gross output. An upward bias in the price deflator for an intermediate input would cause real intermediate inputs to be understated. Thus, real value-added and productivity would be overstated in sectors using this input, whereas the upward bias would cause productivity to be understated in the sector producing the input.

Measuring Service Sector Productivity

Measuring output may be particularly problematic in the service sector.[1] In some service industries such as banking, there is not even consensus on the appropriate concept of output. Moreover, output in some sectors (such as some components of business services and financial services) is often imputed by Statistics Canada from the levels of inputs, thereby biasing downwards the sectoral measures of productivity. These difficulties imply that extra caution is warranted when using productivity data for many of the service sectors.[2]

A final issue concerns the comparability of productivity data from different countries. Newly released data can be revised significantly over time. This means that currently available data may sometimes be a misleading indicator of the true differences in performance across countries. The Canada-U.S. comparisons reported in this article could also be misleading to the extent that the national statistical agencies use different techniques (such as different methods of quality adjustment) to construct their data.[3] Statistics Canada's recent move to capitalize software expenditures has eliminated one of the differences in methodology.

1. The April 1999 special issue of the *Canadian Journal of Economics* contains articles on service sector productivity. Maclean (1997) also discusses measurement issues in the service sector.

2. A Statistics Canada study (Beckstead, Girard, and Harchaoui 2001) assigns the productivity data for each sector a rating of "reliable," "moderately reliable," or "unreliable." Business services and finance, insurance, and real estate are two of the service sectors receiving the lowest ranking based on perceived shortcomings in the methods used to construct the real output series. Productivity data for manufacturing are given a rating of "reliable."

3. Harchaoui, Kaci, and Maynard (2001) discuss the comparability of productivity data published by the Canadian and U.S. statistical agencies.

depends on the trend level of productivity, forming a view on future inflationary pressures requires taking into account the expected future path of productivity. Knowledge of the determinants of productivity growth and of the prospects for future growth are therefore important for the conduct of monetary policy.

This article describes the trends in productivity growth in Canada since the early 1960s and summarizes our current knowledge about the causes of the historical patterns. Particular attention is given to assessing the contribution of ICT to the recent divergence in productivity growth between Canada and the United States. Other determinants of productivity growth, such as human capital and a country's openness to international trade and investment, are also discussed.

Formal international comparisons of productivity growth are restricted to the Canada / U.S. case. The focus on the United States is motivated by its position as Canada's major trading partner and productivity leader in many sectors. In addition, Canadian data are probably more comparable with U.S. data than with those for many other countries.

Past Trends in Canadian Productivity Growth

In this section, the broad trends in labour productivity growth in Canada over the past four decades are summarized. Table 1 shows average rates of productivity growth for the total business sector and the manufacturing sector over selected subperiods.[4]

The productivity performance of the Canadian business sector since the early 1960s can be separated into two distinct periods: 1962–73 and 1974–2001. The annual change in labour productivity 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 period of rapid productivity gains in the United States—growth increased modestly to 1.6 per cent.

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 *trend* productivity growth. This is a difficult question because year-to-year changes in productivity growth can be affected by cyclical movements in output. Since productivity growth tends to move pro-cyclically,[5] 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).

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

A productivity slowdown also occurred in the U.S. business sector after 1973. Unlike the Canadian case, however, a significant pickup was observed over the 1996–2001 period, as the average growth rate in labour productivity increased 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 difference between Canadian and U.S. performance was even greater in the manufacturing sector, where the average growth increased to almost 5 per cent in the United States. The pickup in U.S. productivity growth was broadly based, since higher

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.

4. This article uses data available up to March 2002.

5. 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.

rates were also observed in the service sector, most notably in wholesale and retail trade (Rao and Tang 2001).

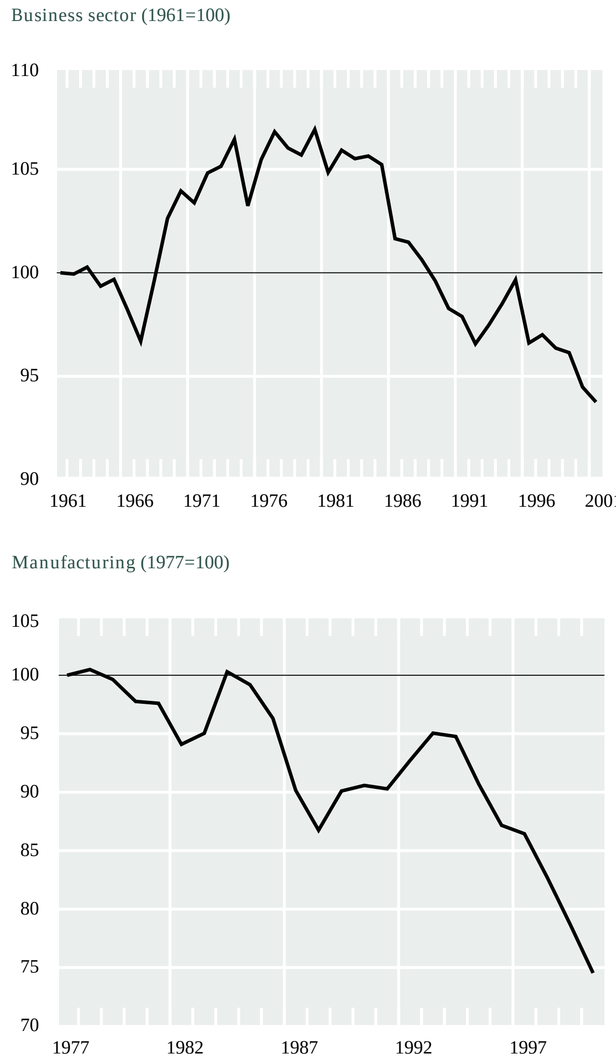
Over the 1996–2001 period . . . labour productivity growth in the U.S. business sector [was] one percentage point above the Canadian rate.

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 1 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.[6] Periods of convergence towards (divergence from) U.S. levels occur when the index of relative productivity in Chart 1 is rising (falling). 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 decline reflects the increase in U.S. growth (Chart 2).

In the manufacturing sector, there was quite strong convergence towards U.S. productivity levels from the early 1960s until the mid-1970s.[7] 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 1). 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 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).[8]

Chart 1

Relative Labour Productivity in Canada vs. the United States



A comparison of Canadian and U.S. trends at a more disaggregated level shows whether the productivity

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

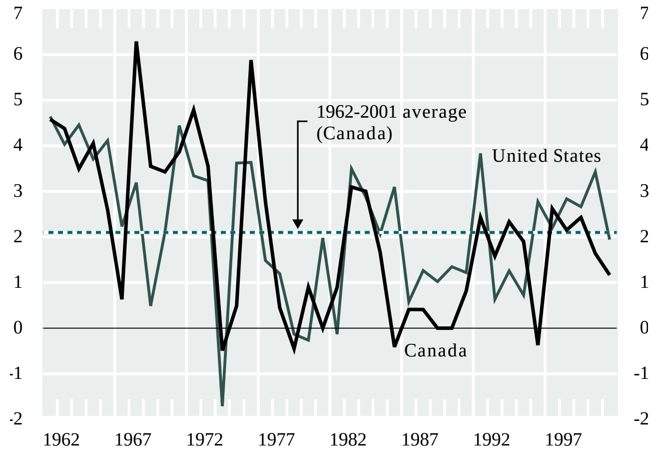
7. Because of data availability, comparisons of the Canadian and U.S. manufacturing sectors in the 1960s and early 1970s must use productivity data calculated from different measures of output. U.S. data for this period are based on a measure of gross output less intra-sectoral sales and transfers, whereas the Canadian data use real value-added. The graph for the manufacturing sector (Chart 1) covers the 1977–2000 period for which data are available for both countries on a value-added basis.

8. International comparisons of productivity levels are difficult, because output levels must be converted to a common currency using a conversion factor based on cross-country differences in producer prices. Typically, there is limited information on these price differences.

Chart 2

Labour-Productivity Growth

Business sector



gaps are widespread throughout the economy or concentrated in certain sectors. From 1995 to 1999, Canada recorded stronger productivity growth than the United States in primary industries and construction but weaker growth in most of the major service-sector categories (Rao and Tang 2001). In manufacturing, the large gap between Canadian and U.S. rates of productivity growth is explained by very rapid U.S. gains in the electrical / electronic equipment and other machinery and equipment sectors. Rao (2001) reports that, in 1997, Canadian *levels* of labour productivity exceeded those in the United States in only a few resource-based industries and were substantially lower in the machinery and equipment and electrical / electronic equipment sectors.

In summary, Canada's relative productivity performance has deteriorated since the mid-1980s. Most recently, U.S. labour productivity grew at rates significantly above those in Canada and in many other industrialized countries. Possible explanations for these trends are now discussed.

Contributions of ICT to 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 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 3). Similar growth rates were observed in Canada over the same period.

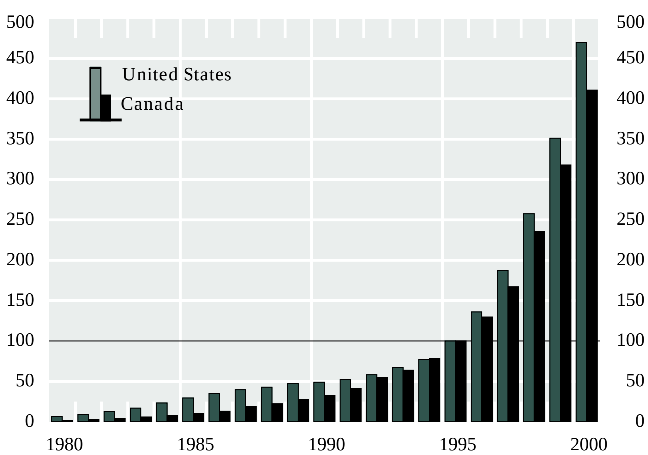
The hypothesized link between ICT investment and productivity growth is consistent with the view that ICT is a "general-purpose technology" with productivity-enhancing applications in many sectors of the economy. To give just a few examples, ICT may raise productivity by providing more efficient means of processing 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 on labour productivity using the "growth-accounting" methodology. As described in Box 2, this technique can be used to measure the contribution to labour-productivity growth 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.

Chart 3

Stock of Computers 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.

Box 2: 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:

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

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.

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:

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

Thus, labour-productivity growth can be decomposed into the contributions from the change in multifactor productivity and the change in the capital-to-labour ratios (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). When analyzing the total effect of ICT on labour productivity, they distinguish between the contribution to productivity growth from the *use* of ICT goods 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.

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 the contributions from the sectors that *produce* ICT goods. The former is measured by the 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 now presented below.

U.S. studies

Jorgenson, Ho, and Stiroh (2001) applied the growth-accounting methodology to U.S. data for the private sector.[9,10] 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 and MFP gains in ICT-producing sectors rose to 1.27 percentage points (Table 2). Increased ICT use explained almost 50 per cent of the *acceleration* in the rate of labour-productivity growth over this period, while ICT production contributed another 30 per cent.[11]

Gordon (2000) went a step further by separating the observed increase in U.S. productivity growth in the second half of the 1990s into estimates of the increase in trend productivity growth and the cyclical effect. After accounting for improved methods of price deflation and changes in labour quality, he estimates that the increase in trend labour-productivity growth was 0.64 percentage points, with the pickup coming largely from ICT capital deepening and faster MFP growth in the computer-producing sectors.

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.

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)

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.[12] 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 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

9. Jorgenson, Ho, and Stiroh's measure of output is broader in coverage than the measure used to construct the official U.S. productivity data. 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.

10. 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.

11. 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.

12. 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.

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.[13] 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 ICT accounts for much 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 2, 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).[14] 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).

Growth-accounting analysis provides estimates of the contribution of ICT to aggregate productivity growth. Baldwin and Sabourin (2002) provide microeconometric 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

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.

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

14. 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.

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).

ICT accounts for much of the recent divergence in labour-productivity growth between Canada and the United States.

The lagged effects of ICT investment

Attempts to identify the effects of ICT investment are complicated by evidence of significant lags between the timing of these investments and their full impact on productivity. Using data for large U.S. firms, Brynjolfsson and Hitt (2000a) find 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. Thus, ICT investment appears to be a leading indicator of productivity growth.

One explanation for the long lags is that firms must fundamentally alter their business practices and organizational structures in order to fully exploit the advantages of these new technologies. It may take time for firms to learn what changes are needed to make effective use of new technologies, and delays may also occur because these adjustments are costly and time-consuming. As a result, the productivity gains from information technologies will rise over time as firms are gradually able to implement these changes. Schaan and Anderson (2001) report survey evidence of these types of adjustment problems in the Canadian manufacturing sector. 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 on an ongoing basis 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.

Other Determinants of Productivity Growth

The previous section highlighted the role of information technology, given its prominence in recent discussions. This section considers a broader set of factors that determine productivity growth. Relevant empirical evidence 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.[15]

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, human capital formation, and openness to trade and investment. In various ways, each factor strengthens productivity growth by promoting innovation and the diffusion of new technologies. A brief overview of Canadian evidence on these issues is provided below, as well as a review of the importance to aggregate productivity growth of resource reallocation across different firms in the same industry. Recent discussions regarding the relationship between the exchange rate and productivity are also summarized.

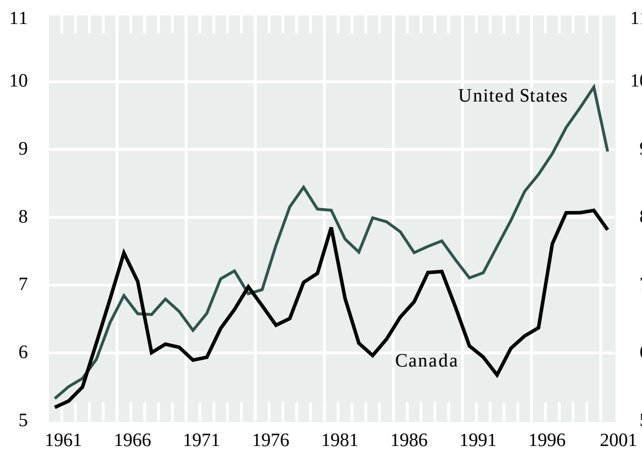
Investment in machinery and equipment

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 4). 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.

15. 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 4

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



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 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. 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.

Investment in human capital

Increases in human capital can contribute 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) or increased quality. 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). 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.

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 in international exams on reading, mathematics, and science (Sweetman 2002).

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.

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, Wu, 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.[16] These R & D spillover effects are particularly

16. 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).

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).

Micro evidence: Implications for aggregate productivity growth

There is an extensive body of literature from researchers who have examined productivity using micro data for individual firms or establishments. Two stylized facts emerge from these studies: (i) there is considerable heterogeneity of levels and growth rates of productivity across firms in the same sector; and (ii) there is 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 stylized facts occur 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). These findings imply that a significant share of aggregate productivity growth can be attributed to resource reallocation across different firms in the same industry. Thus, structural and regulatory policies affecting the entry / exit decisions of firms and factor mobility will have an impact on aggregate productivity growth.

Micro evidence may also help to condition our judgment when we form a view on future rates of trend productivity growth. For example, small- and medium-sized firms are less likely to adopt new advanced technologies, and adoption rates by these firms are lower in Canada than in the United States (Baldwin and Sabourin 1998).[17] Since small firms account for a larger share of manufacturing output in Canada (Baldwin, Jarmin, and Tang 2002), productivity gains from investment in advanced technologies could occur here at a slower pace.

Exchange rate effects

Courchene and Harris (1999) have suggested that depreciation of the Canadian dollar may have contributed to the deterioration in the relative productivity performance of Canada since the 1980s. Advocates of this hypothesis have identified two potential channels for the adverse effects on productivity. First, by raising the cost of imported capital goods, exchange rate depreciation could lower the domestic capital-to-labour ratio and the relative productivity of Canadian producers. In addition, Courchene and Harris claim that domestic firms may have become less vigilant in their efforts to reduce costs and improve productivity, because depreciation has sheltered them from the pressures of global competition. This argument is inconsistent with the standard theoretical assumption of profit-maximizing behaviour, since it implies that firms have foregone opportunities to increase profitability by raising productivity. Lafrance and Schembri (2000) and Laidler and Aba (2002) provide more detailed critiques of the Courchene-Harris hypothesis.

Rao and Tang (2001) demonstrate that ICT manufacturing accounts for all of the divergence in productivity growth between the Canadian and U.S. manufacturing sectors in the second half of the 1990s. If exchange rate effects were a major cause of the weaker productivity growth in Canada, we would expect the productivity differences to be more broadly based across the manufacturing industries. Furthermore, in some sectors that have supposedly been sheltered by the exchange rate (such as primary industries, transportation equipment, and furniture and fixtures), productivity growth was stronger in Canada than in the United States during the 1990s.

Outlook for Future Productivity Growth

As noted in the introduction, trend productivity growth is an important variable in the decision-making process for monetary policy because it affects the growth rate of an economy's potential output and, therefore, demand pressures relative to overall capacity. This section brings together some of the arguments favouring a pickup in trend productivity growth in Canada.

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

17. 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).

- 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 macro 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 (Jorgenson, Ho, and Stiroh 2001). 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. In addition, 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.

It seems reasonable to anticipate some increase in trend productivity growth in Canada relative to the levels observed since the mid-1970s.

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.[18] 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.

18. The focus of Canadian monetary policy on inflation control can be helpful in dealing with this uncertainty about trend productivity growth and potential output. For example, if actual inflation is persistently lower than projected, it would indicate that potential output is probably greater than the current estimate.

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