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Contribution of ICT Use to Output and Labour-Productivity Growth in Canada

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Abstract

There is ample evidence that information and communication technologies (ICT) contributed significantly to the surge in output and labour-productivity growth in the United States in the late 1990s. Does Canada share the U.S. experience? Has ICT influenced the trend productivity and output growth? Answers to these questions will help improve the Bank's forecasts of inflationary pressures. This paper examines the first question. A simple growth-accounting exercise suggests that, in contrast to the United States, Canada did not experience an acceleration in the contributions of ICT use to output and labour-productivity growth.

JEL classification: 04, 05
Bank classification: Productivity

Résumé

Plusieurs études permettent de croire que les technologies de l'information et de la communication (TIC) ont contribué de façon importante à la vive accélération de la croissance de la production et de la productivité du travail aux États-Unis durant la deuxième moitié des années 1990. Observe-t-on le même phénomène au Canada? Les TIC ont-elles influé sur le taux de croissance tendanciel de la productivité et de la production? Répondre à ces questions aidera la Banque à améliorer ses prévisions relatives aux pressions inflationnistes. Cette étude se penche sur la première question. Une simple analyse des composantes de la croissance fait ressortir que contrairement aux États-Unis, les gains de production et de productivité du travail liés à l'utilisation des TIC n'ont pas augmenté au Canada.

Classification JEL : 04, 05
Classification de la Banque : Productivité

1. Introduction

The role of monetary policy in Canada is to keep inflation low and stable. One of the advantages of this environment is that it moderates the negative impact of inflation on investment decisions. The resultant benefits to society are higher output and productivity growth. In following this "pro-productivity" policy, the Bank must closely assess macroeconomic conditions in the economy. Since it takes about 6 to 8 quarters for monetary policy actions to have their full effect on prices, the policy-making process pays careful attention to the difficult task of forecasting inflationary pressures. A common means of doing this is the output gap — the deviation of current output from its potential. The output gap, however, cannot be measured precisely. For instance, an underestimation of the (unobservable) level of potential output will lead to an overestimation of inflationary pressures. The Bank may then be inclined to pursue a tight monetary policy when in fact it need not. In Figure 1 we plot the core inflation rate for Canada, which was persistently below the 2 per cent midpoint of the inflation-targeting range in the latter half of the 1990s, except for some periods in 1996. This figure can be interpreted as being consistent with the aforementioned difficulties, although other factors could be at work.

To avoid monetary policy errors, the key issue for the Bank is to improve its macroeconomic forecasts. The strong output and productivity growth of the U.S. economy, along with low inflation and unemployment in the late 1990s, has led to the speculation that there could be a change in trend productivity and output growth. Recent studies in the United States (for example, Haimowitz 1998, Jorgenson and Stiroh 2000, Oliner and Sichel 2000, Whelan 2000a) examine the role of information and communication technologies (ICT) in contributing to this surge in output and productivity growth. It is important to know the exent to which Canada shares the U.S. experience. More specifically, two questions are of immediate importance: (i) the extent to which ICT investment has contributed to output and labour-productivity growth recently, and (ii) the extent to which ICT investment spending has influenced trend productivity and hence potential output growth. The answers to these questions will lead to a better assessment of inflationary pressures, and thereby improve the macroeconomic forecasts used in monetary policy decisions.

The work of Oliner and Sichel (2000) suggests that slightly over 20 per cent of U.S. output growth over the 1996-99 period can be attributed to the *use* of ICT and approximately 10 per cent to the *production* of ICT components (computer hardware and semiconductors). Moreover, 37 per cent of labour-productivity growth is attributed to “capital deepening” from the use of ICT. Jorgenson and Stiroh (2000) calculate a higher contribution of approximately 43 per cent to total labour-productivity growth.

A common finding in the U.S. studies is that of an acceleration in output and labour-productivity growth over the period 1991-95 to 1996-99; labour productivity accelerated by 1.05 percentage point, of which the use of ICT contributed almost one-half and the production of ICT a little less than one-fifth. Gordon (2000), on the other hand, argues that acceleration in multi-factor productivity (MFP) is primarily concentrated only in the durable-goods sector (which includes the ICT-intensive industries). According to his calculation, outside of this sector there has been no rise in trend MFP. Gordon concludes that the use of computers across the non-durable-goods sectors has made a negligible contribution to the recent acceleration in labour productivity. Moreover, his calculations indicate that, controlling for computer spending in the non-durable-goods sector, the MFP has actually declined.

In this paper, we conduct a simple growth-accounting exercise for Canada to document the contribution of ICT use to output and labour-productivity growth.[1] Our definition of ICT capital

[1]We focus on ICT use alone because ICT production (which includes computer hardware and semiconductors) is small in Canada relative to the United States. Moreover, Oliner and Sichel (2000) have stressed the importance of ICT use relative to ICT production in interpreting the U.S. experience of the late 1990s. Also, recent work by Stiroh (2001) suggests that “spillovers” from ICT production and network effects, which may influence total factor productivity, are quantitatively small.

includes computer hardware, software, and telecommunications equipment. We use the chain-weighted data released by Statistics Canada in June 2001 for our growth-accounting exercise.[2]

In related work, Schreyer (2000) examines the contribution of ICT to output and MFP growth for the G-7 countries for the period 1980-96. His study does not examine the implications for labour productivity, and the post-1996 period which, in the United States, marked an important phase and is central to the debate mentioned above. Our analysis is similar to Haimowitz (1998), who considers the contribution of computer spending to output growth in the United States over the 1982-96 period. Macklem and Yetman (2001) examine the behaviour of prices in Canada using Phillips curve analysis to identify whether the Canadian economy is on a path of higher productivity growth as experienced in the United States. While our paper complements their work, our methodology and focus are different. Muir and Robidoux (2001) examine the influence of information technology on potential output and productivity growth in Canada. Their definition of information technology, however, does not include computer software and telecommunications equipment. Rao and Tang (2001) examine the contribution of ICT to productivity growth in Canada using industry-level data. Harchaoui et al. (2002) examine the composition of investment and the growth of capital services across a broad asset class. They conduct a growth-accounting excercise to examine the contribution of this broad asset class, including ICT, to output and productivity growth.

This paper is organized as follows. In section 2 we outline the growth-accounting framework. In section 3 we describe the data. Section 4 presents our main findings. Section 5 concludes.

[2]The chain-weighted methodology overcomes the biases introduced in the fixed-weight methodology, especially when some components of GDP, such as ICT capital, experience sharp declines in their relative prices (see Whelan 2000b for details).

2. Growth-Accounting Framework

Consider an aggregate neoclassical Cobb-Douglas production function for the non-farm business sector:

$$Y_t = A_t L_t^{\alpha_l} K_{h,t}^{\alpha_h} K_{s,t}^{\alpha_s} K_{tc,t}^{\alpha_{tc}} K_{o,t}^{\alpha_o}. \tag{1}$$

Y_t denotes the aggregate output, L_t hours worked, $K_{h,t}$ the stock of computer hardware, $K_{s,t}$ the stock of computer software, and $K_{tc,t}$ the stock of telecommunications equipment. $K_{o,t}$ denotes the stock of all other types of capital. A_t is the exogenous MFP. We define the capital stock of ICT as $K_{ict} \equiv K_{h,t} + K_{s,t} + K_{tc,t}$.[3] Under the Cobb-Douglas assumption, the $\alpha' s$ denote the output elasticities of each input. The assumptions of perfect competition and constant returns to scale in production imply that the output elasticities equal the respective income shares, and sum to one.

In the standard growth-accounting framework of Solow (1957), the production function in (1) is expressed in terms of growth rates[4]:

$$\Delta y_t = \Delta a_t + \alpha_l \Delta l_t + \alpha_h \Delta k_{h,t} + \alpha_s \Delta k_{s,t} + \alpha_{tc} \Delta k_{tc,t} + \alpha_o \Delta k_{o,t}. \tag{2}$$

The expression

$$\alpha_h \Delta k_{h,t} + \alpha_s \Delta k_{s,t} + \alpha_{tc} \Delta k_{tc,t} \tag{3}$$

is the contribution of the *use* of ICT spending to output growth. The term in (3) depends on (i) the income shares of computer hardware (α_h), software (α_s), and telecommunications equipment (α_{tc}), and (ii) the growth rate of stocks of computer hardware ($\Delta k_{h,t}$), software ($\Delta k_{s,t}$), and telecommunications equipment ($\Delta k_{tc,t}$). The income shares are not observable and therefore have to be estimated. We follow Hall and Jorgenson's (1967) methodology, widely used in the literature on growth accounting, to compute the income shares:

[3] Since the stock of ICT capital is an input in (1), we are assuming that firms substitute ICT capital for other types of capital in response to changes in the relative prices of inputs.

[4] The growth rate of a variable X_t is $\Delta x_t \equiv x_t - x_{t-1}$ and $x_t \equiv \ln(X_t)$.

$$\alpha_j = \frac{(i + \delta_j - \Delta P_j) P_j K_j}{PY}; \quad j = h, s, tc. \tag{4}$$

In Equation (4), i is the nominal private competitive net rate of return, which is the same for all assets.[5] The term δ_j is the economic depreciation rate for type-j capital stock, ΔP_j is the rate of nominal capital gain (or loss, as in the case of computers) on type-j capital stock, $P_j K_j$ is the nominal stock of type-j capital, and PY is the nominal income. For example, the interpretation of α_h in (4) is that a unit of nominal stock of computer hardware earns a gross rate of return $(i + \delta_h - \Delta P_h)$.[6] Therefore, the total nominal stock of computer hardware, $P_h K_h$, generates a nominal flow of income equal to $(i + \delta_h - \Delta P_h) P_h K_h$. Expressing this term as a fraction of nominal income, PY, gives the income share for computing equipment. The product of the income share and the growth rate of the stock of computing capital gives the contribution to growth. A similar interpretation applies to the income shares of software and telecommunications capital.

To find the contribution of the use of ICT capital to labour-productivity growth, we subtract the growth in labour input, Δl, from both sides of (2), and use the fact that $\alpha_l + \alpha_h + \alpha_s + \alpha_{tc} + \alpha_{oc} = 1$. This yields

$$\Delta y_t - \Delta l_t = \Delta a_t + \alpha_h(\Delta k_{h,t} - \Delta l_t) + \alpha_s(\Delta k_{s,t} - \Delta l_t) + \alpha_{tc}(\Delta k_{tc,t} - \Delta l_t) + \alpha_o(\Delta k_{o,t} - \Delta l_t), \tag{5}$$

which says that the growth in output per hour worked (labour productivity) depends on the growth in capital per hour worked (capital deepening) and the growth in total factor productivity. The expression

$$\alpha_h(\Delta k_{h,t} - \Delta l_t) + \alpha_s(\Delta k_{s,t} - \Delta l_t) + \alpha_{tc}(\Delta k_{tc,t} - \Delta l_t) \tag{6}$$

[5] The firms are assumed to choose their capital stocks optimally, so that each capital asset earns the same (net) competitive return, i. In our simple framework, we abstract from influences of corporate taxes or incentives, such as tax credit on the income shares. Further, we consider a weighted average of debt and equity to proxy for i.

[6] This term is ex-post gross return, as used in the recent growth-accounting literature.

indicates the contribution of *capital deepening* in ICT to labour-productivity growth.

3. Data

We use annual Fisher chain-weighted data for the period 1988-2000. Appendix A describes variables and data sources. The capital stock series for each ICT component were obtained from Statistics Canada's Investment and Capital Stock Division. The output series we use accounts for the capitalization of software.

Figure 2 shows the growth rates of labour productivity in Canada and the United States. The late 1990s are marked by a mediocre productivity performance in Canada relative to the United States. Figure 3 shows output growth, labour-input growth, and labour-productivity growth for Canada over the 1988-2000 period. Figure 4 shows the price of each ICT component relative to the GDP deflator, and its respective (nominal) investment-to-GDP ratio. Each relative price displays a steady decline. The investment-to-GDP ratios, on the other hand, display a steady rise for computer hardware and software. This ratio for telecommunications equipment exhibits little change over the late 1990s.

We assume that the depreciation of ICT capital occurs at the same rate as it does in the United States. Fraumeni (1997) calculates a depreciation value of 31 per cent for computer hardware and approximately 15 per cent for telecommunications equipment.[7] The depreciation rate for software is 37 per cent, as in Oliner and Sichel (2000).

[7] These values have been used in recent studies cited above.

4. Results

4.1 Income shares and growth rates

Table 1 provides the income shares and growth rates of ICT capital. The income shares of ICT and its components are uniformly lower for Canada relative to the United States for the two subperiods 1991-95 and 1996-2000, respectively.[8] The average income shares of computer software and telecommunications equipment for the late 1990s are less than half of those in the United States. Somewhat surprisingly, the income share of telecommunications equipment has fallen in Canada during the late 1990s.

The average growth rate in the capital stock of computer hardware and software has generally been high in both Canada and the United States (Table 1). The United States, however, experienced a sharp increase in the average growth rate in computer hardware capital during the latter half of the 1990s, whereas Canada experienced a moderate increase in the growth rate of this capital.

4.2 Contribution of ICT use to output growth

Table 2 presents the contribution of ICT use to output growth in Canada. Over the 1996-2000 period, ICT contributed 0.53 percentage points of the 4.75 per cent growth in business sector output. In other words, approximately 11 per cent of the growth over the latter half of the 1990s can be attributed to an increase in ICT use. Harchaoui et al. (2002) report a slightly higher contribution of 0.7 percentage points to the 4.9 percentage point average output growth over the period 1996 to 2000.[9] The corresponding number for the United States, reported by Oliner and

[8]The overall picture for Canada does not change much when we consider the period until 1999.

[9]There are four notable methodological differences between our paper and that by Harchaoui et al. (2002). First, they adjust labour for compositional changes. Second, they compute the net competitive rate of return, i, whereas we assume a weighted average of rates of return on debt and equity. Third, their depreciation rates use the Canadian dataset on the age-price profile, whereas we use the depreciation rates used in Fraumeni (1997) and Oliner and Sichel (2000). Fourth, they consider ICT capital services, whereas we use the ICT capital stocks.

Sichel (2000), is 23 per cent. The important difference between each country is the size of the acceleration of the average contributions from the first half to the latter half of the 1990s. In particular, the percentage point contribution of computer hardware use and telecommunications more than doubled in the United States, whereas it increased substantially only for computer hardware in Canada. To get a clearer picture of the contrast between the relative contributions of ICT use in Canada and the United States, in Figure 5 we compare our results with those of Oliner and Sichel (2000). This figure contrasts the annual contributions of ICT components to output growth. It is evident that the persistent surge in the contribution of ICT use did not occur for Canada.

4.3 Contribution of capital deepening from ICT use to labour-productivity growth

Table 3 presents the contribution of capital deepening from ICT use to labour-productivity growth in Canada.[10] First, over the 1996-2000 period, capital deepening from ICT use contributed a little more than one-quarter to total labour-productivity growth. Relative to the first half of the 1990s, however, labour-productivity growth itself declined from an average of 1.88 to an average of 1.70 over the late 1990s. The average contribution of capital deepening from ICT use increased from 0.33 to 0.45 percentage points over this period. This finding indicates that the decline in average productivity growth over the latter half may be the result of factors other than ICT use. Interestingly, despite the methodological differences reported in footnote 9, Harchaoui et al. (2002) report a similar 0.4 percentage points contribution of capital deepening from ICT use for the period 1996 to 2000.

[10] At this level of aggregation, it is difficult to distinguish between capital deepening and capital widening. The former implies that a fixed set of industries are accumulating ICT capital, and the latter implies that more industries are accumulating ICT capital. A disaggregated analysis is more suitable to distinguish between the two.

Second, the results indicate a compositional change over the 1990s. The contribution of capital deepening from computer hardware use increased, whereas that of software and telecommunications showed little change. In fact, the average contribution of telecommunications is marginally lower for the latter period. Figure 6 shows the annual relative contributions of the three ICT components to labour-productivity growth. In the United States, however, there is no evidence for a similar compositional change. Labour-productivity growth rose sharply from approximately 1.5 per cent over 1991-95 to over 2.5 per cent during the 1996-99 period, and the contributions of capital deepening from ICT use increased for the three components.

Third, the acceleration in labour-productivity growth is correlated with the surge in capital deepening from ICT use in the United States (as documented in the U.S. studies cited above). In contrast, for Canada we observe neither an acceleration in labour productivity nor a surge in the contribution of capital deepening from ICT use (Figures 5 and 6).

5. Conclusion

The detection of changes or shifts in the underlying trend of output and productivity growth is important in the assessment of inflationary pressures in an economy. One potential source of these shifts is the recent surge in ICT in the United States. This raises two important questions: (i) the extent to which the proliferation of ICT use contributed to output and labour-productivity growth, and (ii) whether these contributions have influenced trend growth or are cyclical in nature.

In this paper we conducted a simple growth-accounting excercise to answer the first question. We compared our results with a recent study by Oliner and Sichel (2000). Our main finding is that, compared with the United States, there was no acceleration in the contribution of ICT use to output growth in the late 1990s. Similarly, contributions from capital deepening in ICT use to labour-productivity growth did not exhibit any acceleration.

Future work should address the second question. Data limitations make the trend-versus-cycle decomposition difficult. However, we can gain an understanding of the nature of growth shocks (such as those in the ICT sector), and how they influence trend productivity and output growth within a dynamic general-equilibrium model with investment-specific technological change. Recent papers by Pakko (2000) and Bakhshi and Larsen (2001) apply the framework developed by Greenwood, Hercowitz, and Krusell (1997, 2000) to address this question. An investigation into this area would be useful in suggesting ways to improve the Bank's macroeconomic forecasts.

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Table 1: Income shares and growth rates of ICT capital				
	Canada		**U.S.**: O-S (2000)*	
	91-95	96-00	91-95	96-99
Income share (%)				
ICT	2.68	2.87	5.3	6.3
Hardware	0.76	1.01	1.4	1.8
Software	0.80	0.95	2.0	2.5
Telecom.	1.12	0.91	1.9	2.0
Growth rate (%)				
Hardware	22.40	30.70	17.5	35.9
Software	13.20	13.84	13.1	13.0
Telecom.	4.95	7.68	3.6	7.2

*Oliner and Sichel (2000), Table 1.

Table 2: Contribution of ICT use to output growth				
	Canada		**U.S.**: O-S (2000)*	
	91-95	96-00	91-95	96-99
Output growth (%)†	1.92	4.75	2.75	4.82
ICT**	0.33	0.53	0.57	1.10
Hardware	0.17	0.32	0.25	0.63
Software	0.11	0.14	0.25	0.32
Telecom.	0.06	0.08	0.07	0.15

*Oliner and Sichel (2000), Table 1.

**Contribution is in percentage points.

† Real output growth figures for Canada are based on business sector data.

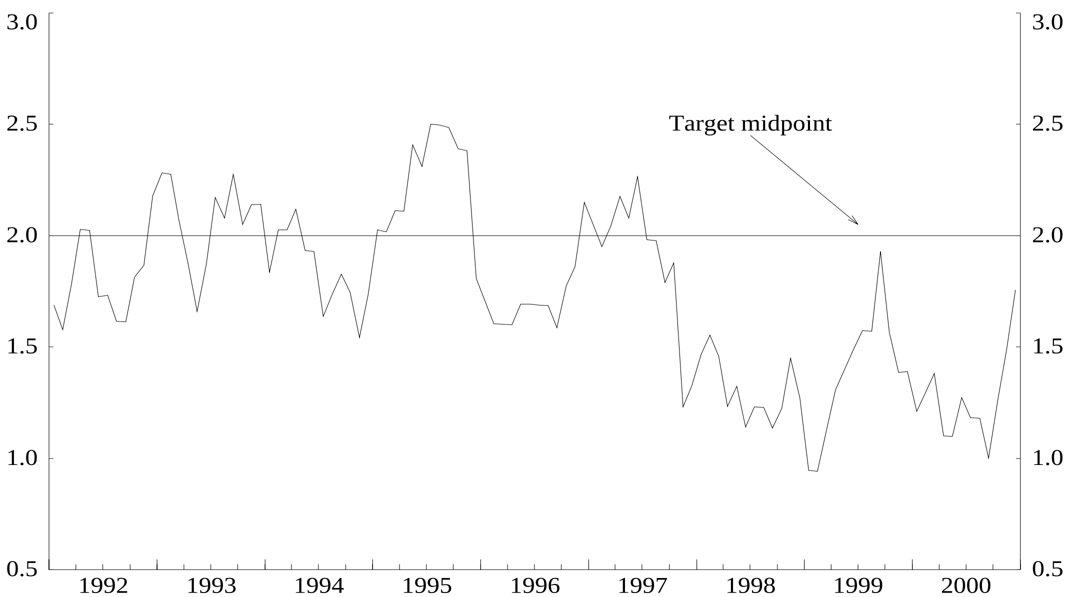
Table 3: Contribution of capital deepening from ICT use to LP* growth				
	Canada		**U.S.**: O-S (2000)**	
	91-95	96-00	91-95	96-99
LP growth (%)†	1.88	1.70	1.53	2.57
ICT capital deepening* **	0.33	0.45	0.51	0.96
Hardware	0.17	0.29	0.23	0.59
Software	0.10	0.11	0.23	0.27
Telecom.	0.06	0.05	0.05	0.10

*LP: labour productivity.

**Oliner and Sichel (2000) Table 1.

***Contribution is in percentage points.

† LP growth figures for Canada are based on business sector data.

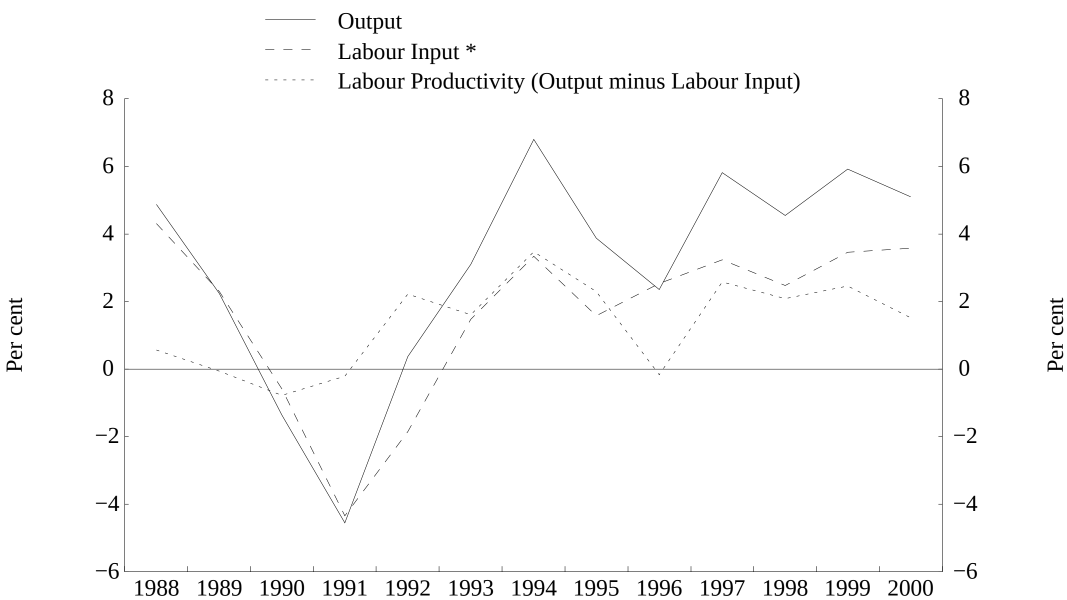


This is the 12−month inflation rate of the consumer price index excluding
the eight most volatile components and the effect of changes in indirect taxes.

Figure 1: Core inflation and the target (midpoint)

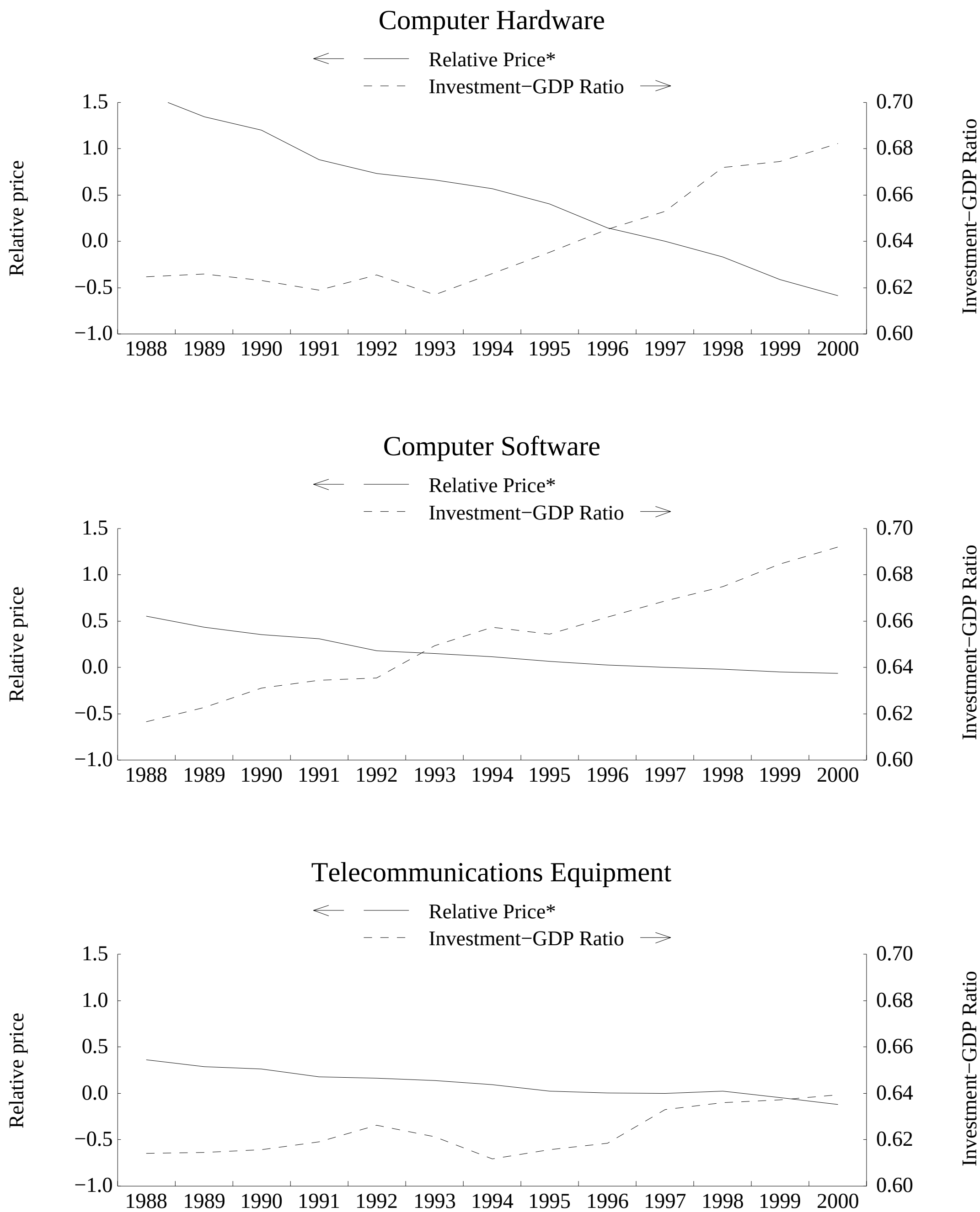
These are growth rates of real output per hour in the business sector.
Source: Bureau of Labor Statistics (PRS84006093) and Statistics Canada (V1409153).

Figure 2: Labour-productivity growth rates: Canada and United States



*Labour input is defined as the number of hours worked.
All calculations are based on data from Statistics Canada, for the business sector.

Figure 3: Output, labour input, labour productivity (annual growth rates)



* The asset price relative to the GDP deflator.
All calculations are based on data from Statistics Canada.

Figure 4: Relative prices and (nominal) investment/(nominal) GDP ratios
(All variables are in logs)

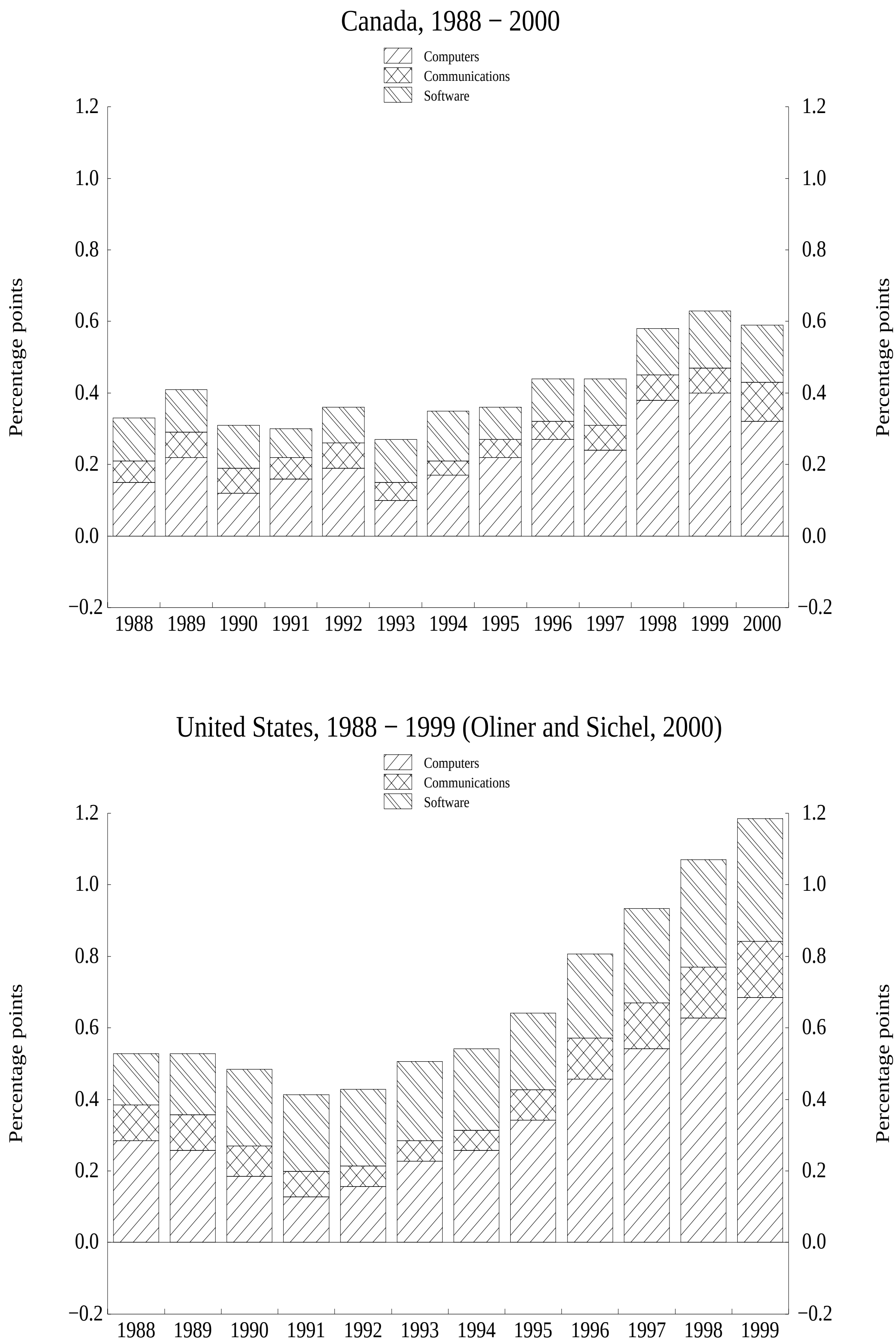


Figure 5: Contribution of ICT use to output growth: Canada vs the United States

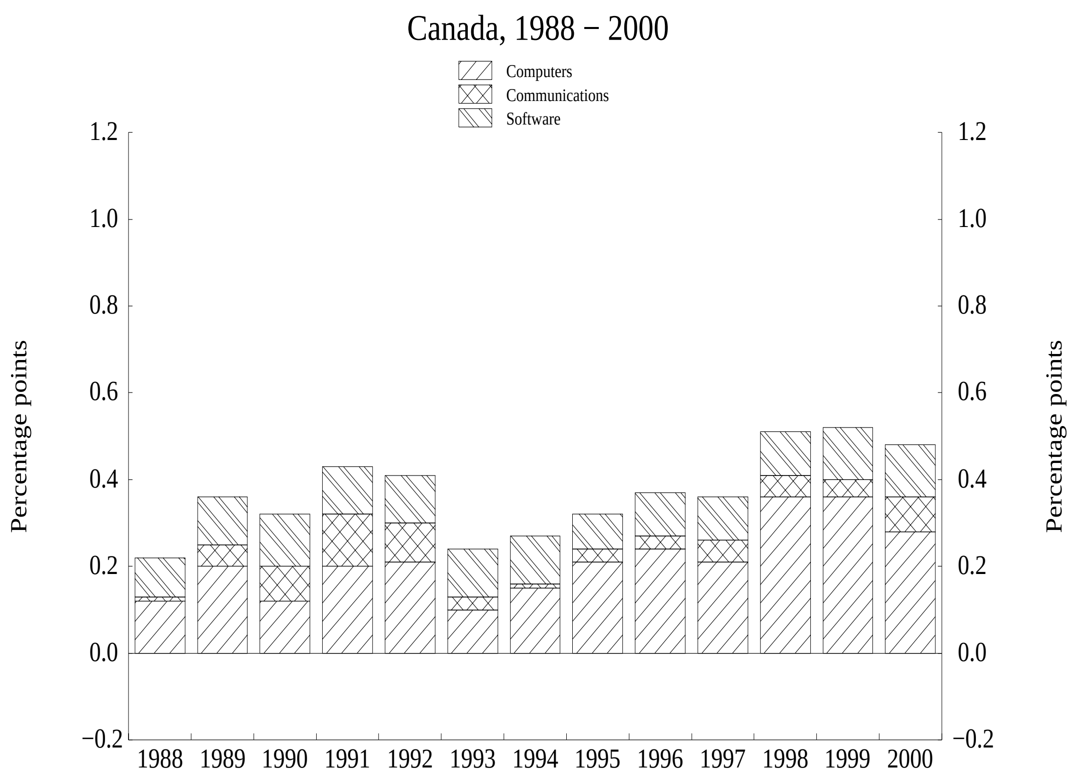


Figure 6: Contribution of capital deepening from ICT use to labour-productivity growth

Appendix A: Data Description

All the real variables refer to chain-weighted Fisher data for the business sector excluding agriculture, unless otherwise indicated. All calculations use annual data (the non-annual series are converted to annual frequency) for the period 1988 to 2000. The series identifiers are from Statistics Canada's CANSIM database.

A.1 Data for Estimation of Income Shares

1. *Nominal net rate of return:* This series is the weighted average rate of return on corporate debt (B14049) and equity (V634654), weighted by the debt-to-equity ratio (V634656).

2. *Geometric depreciation rates:* Computers = 31 per cent, software = 37 per cent, and telecommunications = 15 per cent. The depreciation rates for computers and telecommunications are taken from Fraumeni (1997); the software depreciation rate is taken from Oliner and Sichel (2000).

3. *Growth rate of prices:* The business investment deflator is used for all assets. A price deflator for each asset is obtained by dividing the nominal business investment in that asset by the real chain-weighted business investment in that asset. Computers = V498685/V1992152, software = V1992213/V1992153, and telecommunications = V498689/V1992157.

4. *Nominal net (geometric depreciation) capital stock:* Statistics Canada's Investment and Capital Stock Division has provided us with the official estimates of capital stock of computers (asset code = 6002), software (asset code = 7005), and telecommunications equipment (asset code = 7003) in current and Fisher chained dollars. Statistics Canada uses the following average geometric depreciation rates: computers = 28 per cent, software = 38 per cent, and telecommunications equipment = 10 per cent.

5. *Nominal output:* For 1988 to 1998, we use the GDP at basic prices in current dollars of the business sector (V3860037) minus the GDP at basic prices in current dollars of crop production (NAICS 111) and animal production (NAICS 112) (V3859792). For 1999 and 2000, we use the GDP at basic prices in constant 1997 dollars of the business sector (V2044313) minus the same measure of crop production (V2035518) and animal production (V2035519) multiplied by the implicit price index, 1997=100 (V3840593).

A.2 Data for Real Net Capital Stock

1. *Computers, software, and telecommunications:* The real net capital stock series for each asset is in Fisher chained 1997 dollars, provided by Statistics Canada's Investment and Capital Stock Division.

A.3 Other Variables

1. *Growth rate of real GDP:* We use the quarterly series of real GDP index (1997=100) of business (V1409154) to calculate the growth rates of output. This series accounts for the capitalization of software.

2. *Labour input:* Labour input is defined as the number of hours worked in the business sector (V716822).

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