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The Relationship between ICT Investment and Productivity in the Canadian Economy: A Review of the Evidence

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The Relationship between ICT Investment and Productivity in the Canadian Economy: A Review of the Evidence

Abstract

The objective of this report is to shed light on the relationship between information and communications technologies (ICT) and productivity in the Canadian economy. The first part provides a detailed overview of ICT investment and capital by ICT component (computers, communications equipment, and software), and ICT investment and capital stock per worker by ICT component in Canada for the total economy and for 20 NAICS industries, focusing on trends over the 1980-2005 period. The second part contains a general discussion of ICT and productivity issues, with particular emphasis on the relationship between investment in ICT and productivity. The third part provides a review of the literature on the relationship between ICT and productivity, again with a particular emphasis on Canadian studies.

The key conclusion of the report is that ICT has been the driving force behind the acceleration of productivity growth in Canada and the United States since 1996. However, the potential of ICT has not been fully exploited and we will continue to see significant ICT contributions to productivity growth in coming years. The role for government is to develop appropriate policy frameworks so that the productivity-enhancing effects of ICT can be fully realized.

The Relationship between ICT Investment and Productivity in the Canadian Economy: A Review of the Evidence

Executive Summary

The objective of this report, commissioned by the Telecommunication Policy Review Panel (TPRP), is to shed light on the relationship between information and communications technologies (ICT) and productivity in the Canadian economy in the context of the TPRP mandate to report on the appropriateness of Canada's current ICT investment levels.

This report consists of three parts. The first part provides a detailed overview of ICT investment and capital by ICT component (computers, communications equipment, and software), and ICT investment and capital stock per worker by ICT component in Canada for the total economy and for 20 NAICS industries, focusing on trends over the 1980-2005 period.

The second part contains a general discussion of ICT and productivity issues motivated by questions in the TPRP consultation document, with particular emphasis on questions on the relationship between investment in ICT and productivity; possible justification for a role for government in supporting increased business sector ICT investment; and whether Canadian firms are currently underinvesting in ICT.

The third part provides a review of the literature on the relationship between ICT and productivity, again with a particular emphasis on Canadian studies. Evidence is drawn from aggregate growth accounting studies, industry-level studies, and firm-level case studies in Canada, the United States and other OECD countries..

The key conclusion of the report is that ICT has been the driving force behind the acceleration of productivity growth in Canada and the United States since 1996. However, the potential of ICT has not been fully exploited and we will continue to see significant ICT contributions to productivity growth in coming years. The role for government is to develop appropriate policy frameworks so that the productivity-enhancing effects of ICT can be fully realized.

Part One: ICT Investment and Capital Stock in Canada: An Overview

ICT Investment

In 2005, ICT investment at the total economy level in Canada was $33.2 billion in current dollars, up from $4.2 billion in 1980, the first year for which data are available. The 2005 level of ICT investment represented 17.5 per cent of total non-residential investment and 2.42 per cent of GDP.

ICT investment and capital stock is broken down into three components: computers, communications equipment, and software (including customized, off the shelf, and own account versions). Software currently represents about one half of ICT investment, with computers and communications equipment each representing around one quarter.

Real or chained dollar ICT investment represented 28.4 per cent of total non-residential investment in 2005 and 4.80 per cent of GDP. The much larger shares of chained dollar ICT investment compared to current dollar estimates are due to a downward price trend, which was driven by the massive decline in computer prices, falling an incredible 15.7 per cent per year from 1980 to 2005.

ICT Capital Stock

In 2005, total ICT net capital stock in the total economy in Canada, based on geometric depreciation, was $92.2 billion in current dollars, up more than six-fold from 16.0 billion in 1980. The share of the ICT capital stock in the total non-residential business sector capital stock has risen steadily, from 2.68 per cent in 1980 to 4.31 per cent in 2005.

Due to the fall in the relative prices of ICT capital, chained dollar trends in the ICT capital stock differ markedly from that of current dollar trends. In 2005, the ICT net capital stock for the total economy was $146.8 billion 1997 dollars, up 19-fold from $7.8 billion in 1980. The share of the real ICT capital in total non-residential capital rose nearly nine-fold from 0.84 per cent in 1980 to 7.84 per cent in 2005.

ICT Investment Per Worker

In 2005, ICT investment per worker in the business sector in Canada averaged $2,128 current dollars. Software accounts for around one half of total ICT per worker, while computers and communications equipment each represent around one quarter. There is also great divergence in the use of ICT among industries in Canada. ICT investment per worker in the most ICT-intensive industry is more than 150 times that of the least ICT-intensive industry. This suggests that ICT underinvestment, if it exists, may be sector-specific as one might expect that certain types of ICT would have applications in all industries.

ICT Capital Per Worker

In 2005, ICT capital per worker in the business sector in Canada averaged $6,007 current dollars. Communications equipment accounts for about one half of total business sector ICT capital per worker and computers and software each one quarter. There is even greater divergence in ICT capital intensity among industries than there is for ICT investment. ICT capital per worker in the most ICT capital-intensive industry is 337 times that of the least intensive.

Over the 1987-2005 period, growth in real ICT capital stock per worker considerably outpaced growth in real total capital stock per worker, increasing at an average annual rate of 10.5 per cent compared to only 1.1 per cent per year. However, growth in capital intensity slowed down between 2000 and 2005, with most industries experiencing a decline in ICT capital stock per worker growth.

Part Two: General Discussion of the Relationship Between ICT Investment and Productivity

In general, ICT investment has a positive effect on productivity growth, but the relationship is complex. Different aspects of the ICT investment-productivity nexus discussed in the report are highlighted below.

In a two-factor of production (capital and labour) model, growth accounting methodology allows one to decompose labour productivity growth into two components: changes in capital intensity (the capital/labour ratio), and changes in total factor productivity (the residual unexplained by changes in the capital/labour ratio). If the capital/labour ratio remains constant over time, labour productivity growth equals TFP growth.

ICT investment can affect labour productivity both through the capital intensity and the TFP channels. ICT investment increases the ICT capital stock, which increases capital intensity if labour input increases at a slower rate. Each worker has more ICT capital to work with and will in principle be more productive. In addition, ICT investment and capital stock can directly contribute to TFP growth, and thereby to labour productivity growth, through technological progress. Unfortunately, there is no simple methodology to capture the total effect of ICT investment on labour productivity.

In fact, the basic growth accounting framework for the estimation of the impact of ICT investment on labour productivity growth has a number of serious limitations. First, the impact of ICT investment on labour productivity growth may not occur in the same period in which the investment takes place due to lags. Second, the benefits of ICT investment on firm performance may go well beyond productivity increases and include quality improvements in products and services produced. Third, ICT investments may be so small in magnitude that they have minimal effect on the capital stock, but represent such technological breakthroughs that they raise productivity significantly. Fourth, the net productivity gains from ICT investments may be less than expected because they may also have non-trivial productivity-reducing effects, either directly or indirectly.

At the industry level, our analysis does not show a straightforward relationship between growth in ICT capital intensity and labour productivity growth. For computer capital intensity, the relationship is non-existent. The relationship that exists between communication capital stock per worker and labour productivity is stronger. However, many industries still do not fit well in the picture. Finally, software capital intensity is the only component showing a consistent positive relationship with labour productivity across industries.

The relationship between ICT capital intensity and labour productivity is not straightforward. Trends in labour productivity depend on many variables in addition to ICT capital intensity, such as the business cycle, R&D intensity, profitability, and industry specific input prices. Moreover, the beneficial effects of growth in ICT capital intensity on productivity are likely to be felt with a lag. Finally, investments complementary to ICT investment such as training, the adoption of best practice managerial techniques, and the intensity of competition pressures also influence the impact of ICT investment on labour productivity.

There is no easy answer to the question of whether Canadian businesses under-invest in ICT. Few economists make the argument that Canadian businesses under-invest in structures. More are willing to entertain the idea that businesses can under-invest in machinery and equipment and ICT. In economic terms, under-investment by the private sector can be caused either by an under-estimation of the private rate of return due to imperfect information or by the presence of positive externalities that could justify government intervention. Most economists believe persuasive or convincing evidence that Canadian firms under-invest in ICT due to externalities is still lacking.

In Canada, it is specifically ICT investment that is lagging, not overall investment. The share of total investment to GDP is larger in Canada than in the United States. However, ICT investment as a share of total investment is much lower in Canada and accounts for three quarter of the ICT investment per worker gap with the United States, which was almost 46 percentage points in 2005. Other factors contributing to the Canada-US ICT investment gap include lower levels of labour productivity in Canada and a discrepancy between PPPs for the GDP and investment.

Given the importance of investment to the economy, government should in general pursue policies that support additional investment by the business sector. But the question is whether ICT investment should receive preferential government treatment relative to other types of investments such as structures or non-ICT machinery and equipment. If positive externalities can be identified in terms of ICT investment over and beyond those found in other types of investments, then a case can be made on solid theoretical grounds for government to subsidize such investments. However, weak evidence of such ICT-specific externalities for Canada implies that ICT investment is no different than other types of machinery and equipment investment and does not merit special measures by government.

Part Three: A Review of the Literature on ICT Investment and Productivity

This part of the report reviews selected literature on the impact of investment in ICT on productivity. The important work of Brynjolfsson and Hitt finds that the computer and communication technologies are flexible inputs that allow firms to fundamentally reorganize the production and distribution of goods and services to improve efficiency. But it also stresses that these reorganizations must be accompanied by investment in complementary intangible assets, which are needed so firms can learn how to best use the flexible inputs.

Paul David has made an important contribution to the debate on the impact of ICT in productivity growth by providing an historical perspective. He examined analogous historical episodes involving the elaboration and the diffusion of other general-purpose technologies such as the electric dynamo. These episodes, which he called "techno-economic transitions", involved profound changes, both in breadth and in depth, in the production process. Those changes required decades rather than years, and while in process gave no promise of generating positive macroeconomic results. But over time, the exploitation of the new systems did result in a resurgence in the TFP residual, thus raising labour productivity. The same transition experience appears to have occurred during the introduction of ICT to production processes in the 1990s.

Empirical results, obtained from a number of firm level, industry level and aggregate level studies, on the impact of ICT on productivity and economic growth suggest that ICT contributed positively to labour productivity and economic growth. ICT intensive sectors appear to have been the drivers of aggregate labour productivity growth.

The search for evidence of ICT spillovers is inconclusive. Most studies provided weak evidence of such positive complementary innovations/spillovers effects occurring at the time of investment. However, these could possibly take time to materialize and appear in the data, which one study suggested. In any case, the results should not be taken as a justification for government involvement because of the possible mix up between two distinct effects (spillovers and complementary innovations).

Finally, the most relevant policy suggestions reviewed to make the economic environment more favorable to ICT investment were encouraging skill acquisition by workers and modifying the tax treatment of human capital and venture.

Conclusion

The key conclusion of the report is that ICT has been the driving force behind the acceleration of productivity growth in Canada and the United States since 1996. However, the potential of ICT has not been fully exploited and we will continue to see significant ICT contributions to productivity growth in coming years. The role for government is to develop appropriate policy frameworks so that the productivity-enhancing effects of ICT can be fully realized.

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The Relationship between ICT Investment and Productivity in the Canadian Economy: A Review of the Evidence[1]

Introduction

The objective of this report, commissioned by the Telecommunication Policy Review Panel (TRRP)[2], is to shed light on the relationship between information and communications technologies (ICT) and productivity in the Canadian economy.

This report consists of three parts. The first part provides a detailed overview of ICT investment and capital by ICT component (computers, communications equipment, and software), and ICT investment and capital stock per worker by ICT component in Canada for the total economy and for 20 NAICS industries, focusing on trends over the 1980-2005 period.

The second part contains a general discussion of ICT and productivity issues motivated by questions in the TPRP consultation document, with particular emphasis on the questions on the relationship between investment in ICT and productivity; possible justification for a role for government in supporting increased business sector ICT investment; and the issue of whether Canadian firms are currently underinvesting in ICT.

The third part provides a review of the literature on the relationship between ICT and productivity, again with a particular emphasis on Canadian studies. Evidence is drawn from aggregate growth accounting studies, industry-level studies, and firm-level case studies in Canada, the United States and other OECD countries. A distinction is

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[1] This paper was commissioned by the Telecommunication Policy Review Panel (TPRP) as a background document. It was written by Andrew Sharpe, Executive Director of the Centre for the Study of Living Standards, with the assistance of Olivier Guilbaud and Francois-Alexis Ouégnin for the literature review and Jean-Francois Arsenault, Sharon Qiao, and Elad Gafni for data development. The author would like to thank TPRP Executive Director Alan MacGillivray for the invitation to prepare this document and George Hariton for his support.

[2] The Telecommunications Policy Review Panel was appointed by the Honourable David L. Emerson, Minister of Industry, on April 11, 2005 to conduct a review of Canada's telecommunications policy and regulatory framework. The Panel was asked to make recommendations on how to move Canada toward a modern telecommunications framework in a manner that benefits Canadian industry and consumers. The TPRP mandate includes the making of recommendations on measures to promote the development, adoption, and expanded use of advanced telecommunications services across the economy and in particular to report on the appropriateness of Canada's current levels of investments in ICT. In its consultation paper released in June 2005, the TPRP discussed the relationship between ICT and productivity in the "making the most of technology" section by putting forward 16 questions on ICT and productivity that it was particularly interested in exploring. The Final Report of the TPRP was released in March 2006.

made between studies that examine the effects of communications technologies on productivity, as opposed to studies which look at the combined effect of the information and communications technologies (ICT) aggregate. A key difference between information and communications technologies is the manner in which these technologies affect productivity. Information technologies equipment is generally purchased by firms in all sectors and then used within the firm to improve productivity. Much, but not all, communications technologies equipment is purchased by communication services firms who in turn provide productivity-augmenting communications services to firms in all sectors.

Part One: ICT Investment and Capital Stock in Canada: An Overview

Investment in physical capital is important for growth. It expands and renews the capital stock and enables new technologies to enter the production process. Information and communication technology (ICT) has been the most dynamic component of investment in recent years.

This part of the report provides an overview on trends in ICT investment and capital stock in Canada, focusing on the situation in 2005 and trends over the last quarter century.[3] The focus of the analysis is on both the total economy aggregate and the 20 two-digit NAICS industries. The first section looks at ICT investment, the second ICT capital stock, the third ICT investment per worker, and the fourth ICT capital stock per worker. Because the employment series used only begins in 1987, the third and fourth sections cover the 1987-2005. The first two sections cover the 1980-2005 period.

As will be seen below, trends in current dollar ICT differ markedly from trends in chained dollar or real ICT because of very large falls in the absolute and relative prices of ICT. As in standard practice in the economics profession, current dollar estimates will largely be used for analysis of shares as these estimates reflect current prices, not the prices of an earlier period. Equally, chained dollar estimates will be used for discussion of ICT growth, as these estimates in principle reflect the physical quantity or real value of ICT.

All data used in this report are from Statistics Canada. The estimates of ICT investment and capital stock, which are not publicly available through CANSIM, were obtained from the Capital Stock and Investment Division of Statistics Canada.[4] Estimates of GDP and employment were taken from CANSIM.

[3] This report does not address the issue of lower ICT investment, both on a per worker basis and as a share of GDP, in Canada relative to that in the United States. On this issue, see Sharpe (2005) and CSLS (2005).
[4] The Centre for the Study of Living Standards has developed an ICT data base for Canada (and the United States) with much greater industry detail on ICT investment and capital stock than provided in this report. The database can be accessed at no charge to the public and is updated on a regular basis. The Centre for the Study of Living Standards would like to thank the Information Technology Association of Canada for financial support to maintain this database.

ICT Investment

ICT investment is defined in accordance with the 1993 System of National Accounts. It covers the acquisition of equipment and computer software that is used in production for more than one year. ICT has three components: information technology equipment (computers and related hardware), communications equipment and software. Software includes acquisition of pre-packaged software, customized software and software developed in house. ICT components that are incorporated in other products, such as motor vehicles or machine tools, are included in the value of those other products and are excluded from ICT investment.

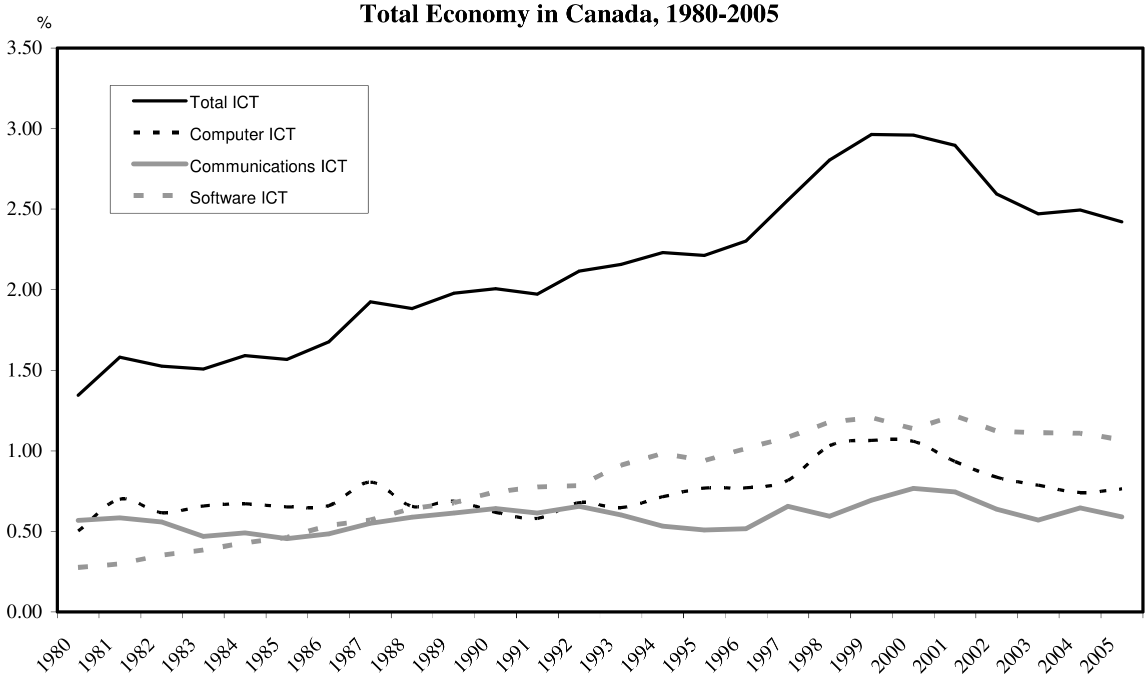
Current dollar estimates

In 2005, ICT investment at the total economy level in Canada was $33.2 billion in current dollars, up from $4.2 billion in 1980, the first year for which data are available (Table 1).[5] The 2005 level of ICT investment represented 17.5 per cent of total non-residential or investment and 2.42 per cent of GDP.

As noted, ICT investment and capital stock is broken down into three components: computers, communications equipment, and software (including customized, off the shelf, and own account versions). In 2005, software was the most important component of business sector ICT investment in Canada, totaling at $14.6 billion (Table 2), followed by computers at $10.5 billion (Table 3), and communications equipment at $8.1 billion (Table 4) . In other words, in 2005 software represented 44 per cent of ICT investment, with computers accounting for 32 per cent and communications equipment 24 per cent.

[5] All tables are found at the end of the report.

Chart 1: Current Dollar ICT Investment/GDP Shares by Component in the Total Economy in Canada, 1980-2005



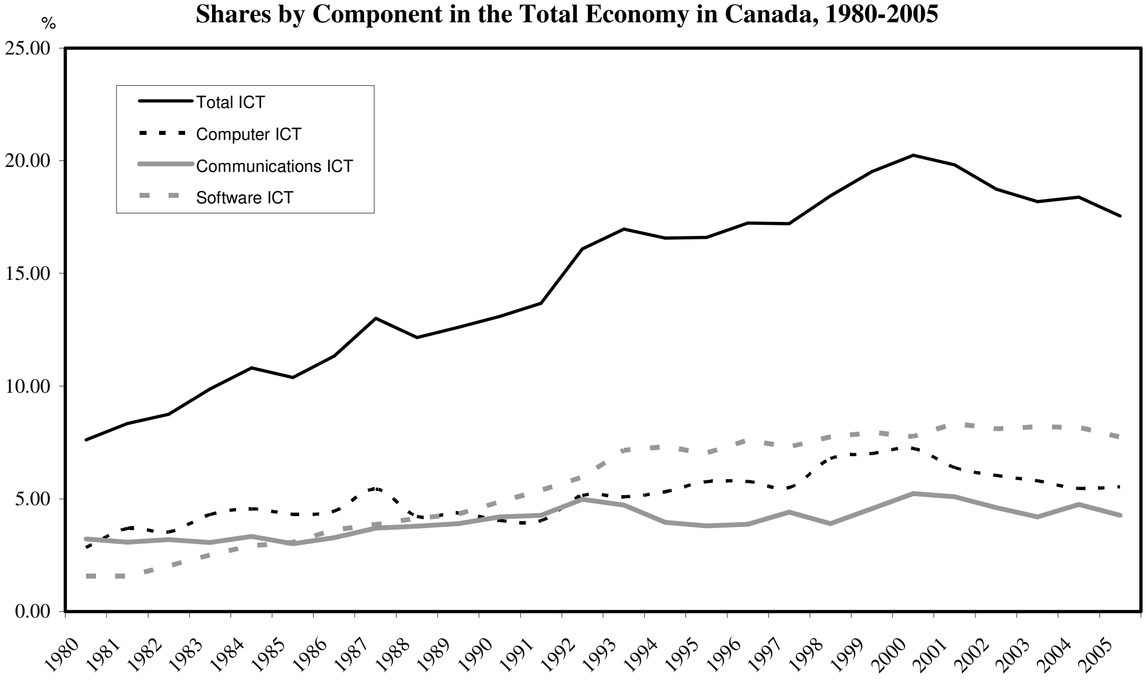
Source : Table 1 to Table 4

Perhaps surprisingly given the attention to ICT in the media, total economy ICT investment, expressed in current dollars, has not increased dramatically in absolute terms as a share of GDP over the last quarter century, rising only 1.08 percentage point (Table 1 and Chart 1). In 1980, ICT investment represented 1.34 per cent of GDP. This share rose to a peak of 2.96 per cent in 1999 and 2000, before falling to 2.42 per cent in 2005. But given the small relative size of ICT investment relative to GDP, the 1.08 percentage point increase represented a 80 per cent rise in the share between 1980 and 2005.

About three quarters of the increase in the ICT investment/GDP share over the 1980-2005 period was accounted for by the quadrupling of the share of software in GDP from 0.28 to 1.07 per cent. About one quarter of the rise was due to the increase in the share of computer investment in GDP from 0.50 per cent to 0.76 per cent. The communications equipment/GDP share contributed only marginally to the rise, increasing only from 0.57 per cent to 0.59 per cent of GDP over the period.

Current dollar total economy ICT investment has risen as a share of non-residential investment, from 7.62 per cent in 1980 to a peak of 20.24 per cent in 2000 before receding slightly to 17.54 per cent in 2005 (Table 1 and Chart 2). This greater rise relative to that experienced by the ICT investment /GDP share is accounted for by the slower rate of increase in nominal investment than GDP over the 1980-2005 period – 5.03 per cent per year versus 6.07 per cent. The large increase in the share of software in total non-residential investment (from 1.56 per cent in 1980 to 7.74 per cent in 2005) accounted for most of the rise in the share of ICT investment in total investment. The computer share of investment rose only from 2.84 per cent to 5.54 per cent. Finally, the communications share of investment increased even less, from 3.22 per cent to 4.27 per cent.

Chart 2: Current Dollar ICT Investment/Total Non-Residential Investment Shares by Component in the Total Economy in Canada, 1980-2005

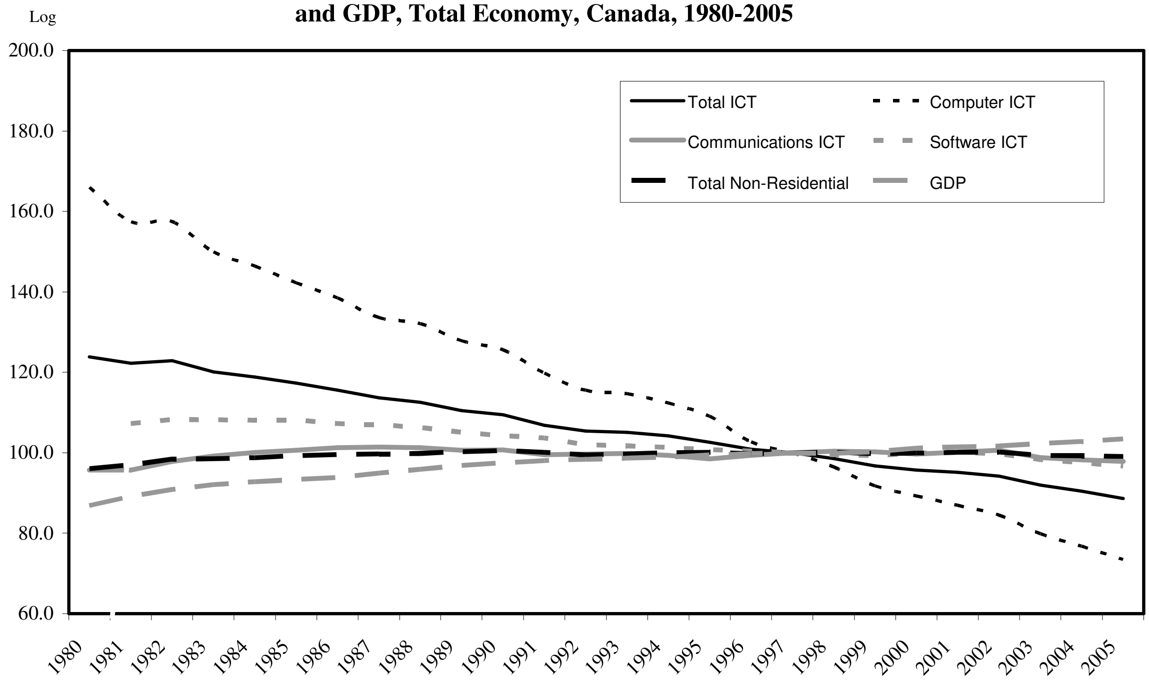


Source : Table 1 to Table 4

The distribution of both the ICT investment and capital stock by industry differ significantly from that of overall non-residential investment and capital stock for certain industries (Table 5). The share of both ICT investment and capital stock in the goods sector is well below its share of total non-residential investment. For example, mining, oil and gas extraction in 2005 accounted for 19.8 per cent of current dollar total non-residential investment and 14.8 per cent of the current dollar capital stock yet it accounted for a meager 1.2 per cent of ICT investment and an even more meager 0.7 per cent of the ICT capital stock.

Conversely, in the service industries in general, the share of both ICT investment and capital stock is above its share of total non-residential investment and capital stock. This is best illustrated by information and cultural industries, which includes telecommunications. In 2005, this sector accounted for 4.9 per cent of total non-residential investment and 4.5 per cent of the capital stock, but for 19.3 per cent of ICT investment and an amazing 38.7 per cent of the total economy ICT capital stock. The low depreciation rate of communications equipment relative to computers and software explains its much larger capital stock share relative to investment.

Chart 3: Deflators for Total ICT Investment and its Components, Total Investment and GDP, Total Economy, Canada, 1980-2005



Source : Table 6.

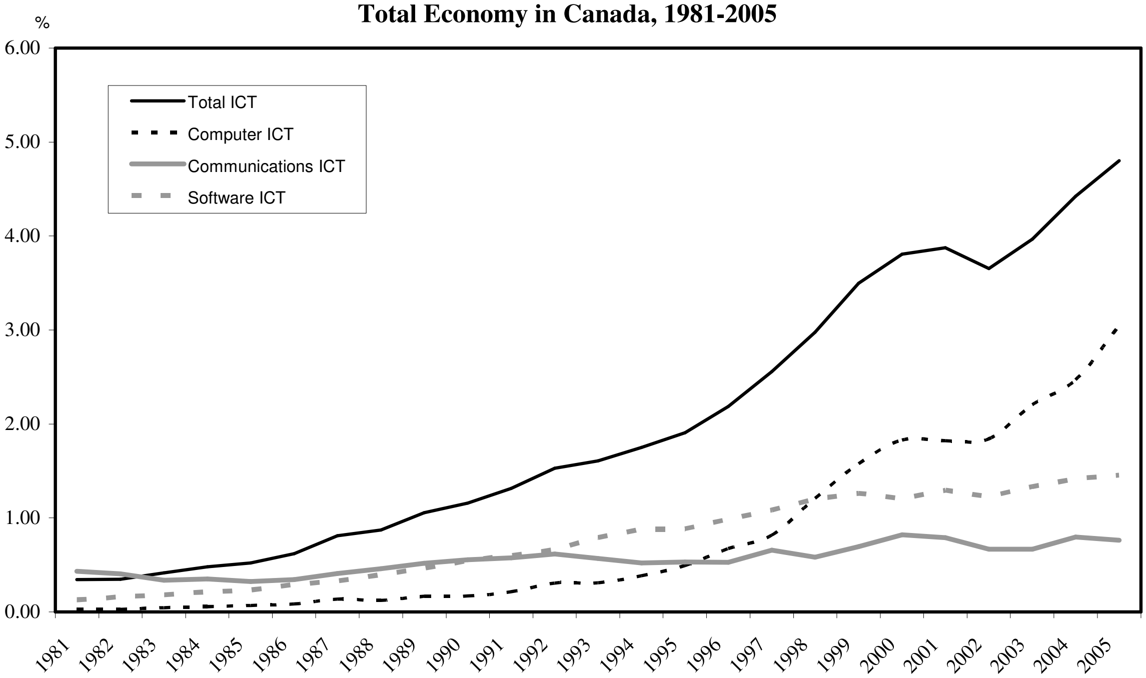
<u>Chained dollar estimates</u>

A completely different picture about the importance of ICT investment in the economy emerges from an analysis of trends in real ICT investment. In 2005, total ICT investment in the total economy in Canada was $56.1 billion in 1997 chained dollars,[6] up from $1.4 billion in 1980 (Table 6). Real or constant price ICT investment, based on Fisher chain estimates for the ICT aggregate,[7] represented 28.4 per cent of total non-residential business sector investment in 2005 and 4.80 per cent of total economy GDP.

This latter figure was near double the current dollar ICT investment share of 2.42 per cent. The greater importance of ICT investment when measured in real terms reflects the fall in the price of ICT investment goods. While the overall total economy GDP deflator rose an average 3.11 per cent a year between 1980 and 2005, and the deflator for non-residential investment rose 0.55 per cent, and the deflator for ICT investment actually fell 6.28 per cent (Table 10 and Chart 3).

[6] Because of the falling relative and absolute price of ICT investment goods, use of an earlier base year than the current 1997 base year would increase the constant dollar or real estimate of ICT investment in the post-1997 period relative to its current level. If current price trends continue, movement from the 1997 base year to a more recent base year, such as 2002, will reduce constant dollar ICT investment estimates for the post-1997 period.
[7] Constant dollar estimates for the three ICT components are Laspeyres indices because there is only one price index for each component. The three ICT components are not additive to the Fisher chain ICT aggregate.

Chart 4: Chained Dollar ICT Investment/GDP Shares by Component in the Total Economy in Canada, 1981-2005



Source : Table 7 to Table 10.

This downward price trend was driven by the massive decline in computer prices, falling an incredible 15.68 per cent per year from 1980 to 2005. In other words, a computer that cost $2,000 in current dollars in 1980 cost only $28 in 2005, a 71-fold fall in prices. This development reflects the huge quality improvement in computers, which is factored into the computer price series through quality adjustment techniques such as hedonic prices.

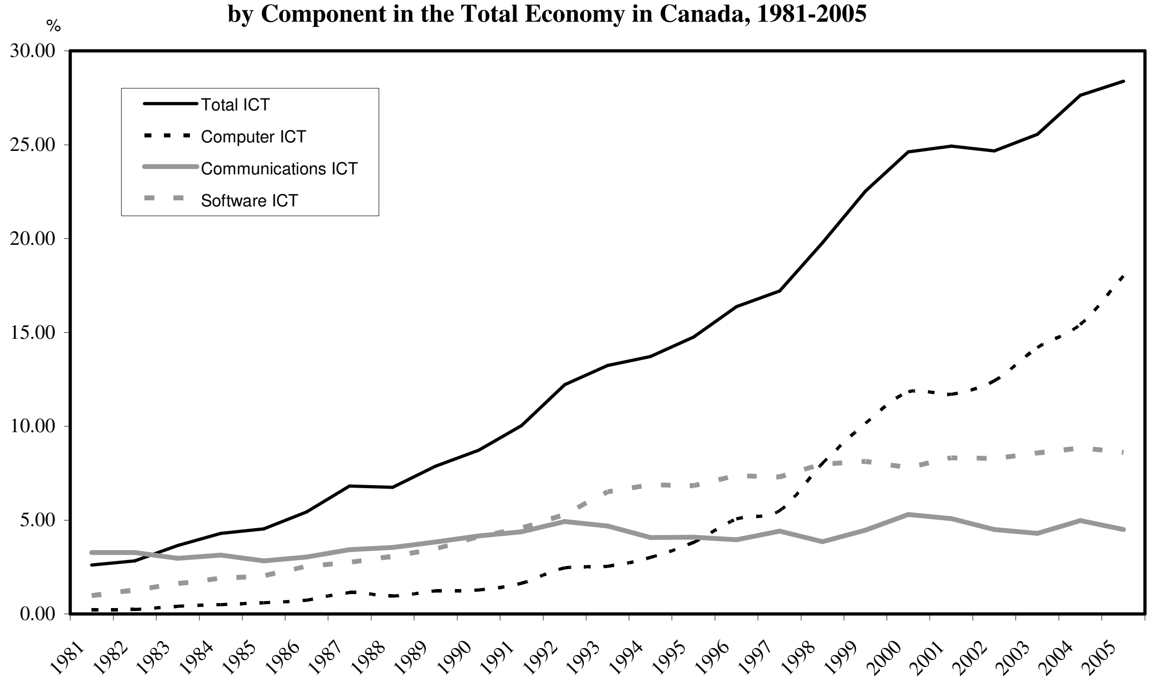
In contrast to the drastic fall in computer prices, prices for software declined only slightly over the same period, 2.00 per cent per year, while prices for communications investment rose marginally, up 0.40 per cent per year.

The massive decline in the relative price of computers led to a major divergence between trends in the current and chained dollar shares of this ICT component in both total non-residential investment and GDP. While the current dollar share of computer investment in total non-residential investment rose only 2.70 points, from 2.84 per cent in 1980 to 5.54 per cent in 2005 (Table 3), the chained dollar share rose 17.90 points from 0.11 per cent to 18.01 per cent (Table 8). Equally, the current dollar share of computer investment in GDP rose only 0.27 points from 0.50 points in 1980 to 0.76 per cent in 2005 (Chart 1) while the chained dollar share increased 3.04 points from 0.01 points from 0.1 per cent to 3.04 per cent (Table 8 and Chart 4).

The divergence between trends in current and chained dollar total investment and GDP shares for communications equipment and software were much smaller than for computers given the much less dramatic changes in their deflators. Nevertheless, the chained dollar shares experienced much greater increases than the current dollar share.

While current dollar share of ICT communications investment in total investment increased 1.05 percentage point from 3.22 per cent in 1980 to 4.27 per cent in 2005, the chained dollar share increased 1.24 points from 3.27 per cent to 4.51 per cent. Equally, the current dollar share for communication investment share of GDP increased 0.02 points from 0.57 per cent in 1980 to 0.59 per cent in 2005, the chained dollar share rose 0.38 points from 0.38 per cent to 0.76 per cent (Table 9).

Chart 5: Chained Dollar ICT Investment/Total Non-Residential Investment Shares by Component in the Total Economy in Canada, 1981-2005



Source : Table 7 to Table 10.

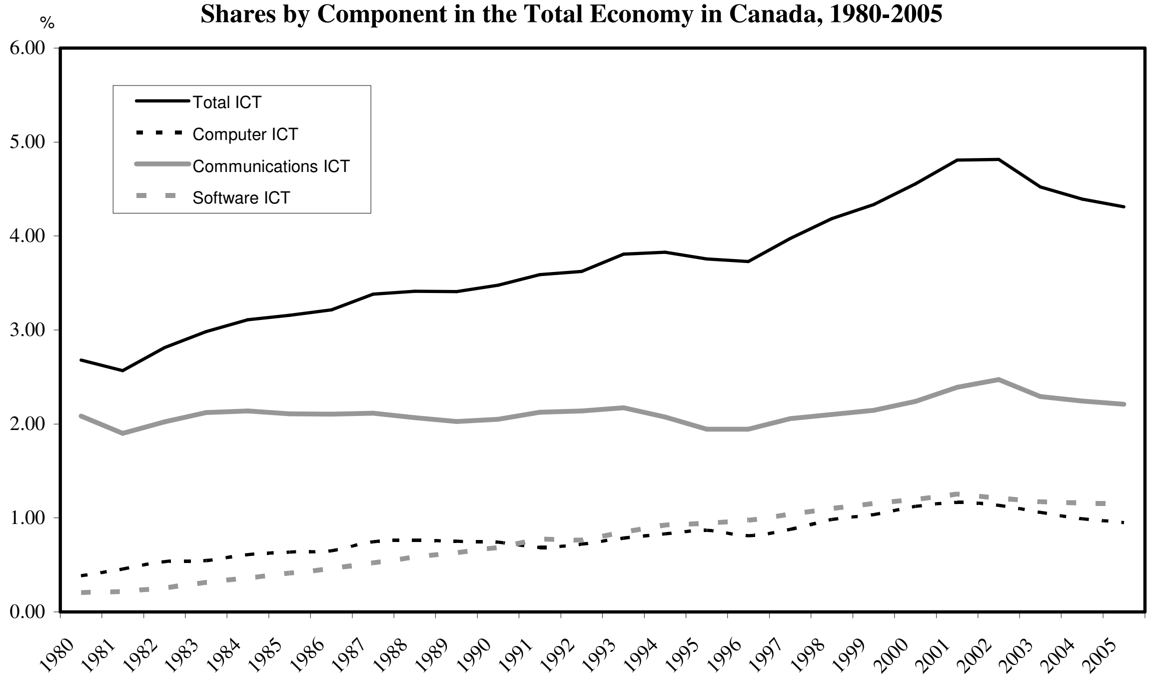
For software investment, the current dollar share in total investment increased 6.18 percentage point from 1.57 per cent in 1981 to 7.74 per cent in 2005, the chained dollar share increased 7.63 points from 0.98 in 1981 (chained dollar estimates for 1980 are not available for software) to 8.61 per cent in 2005. Equally, the current dollar share for software investment in GDP rose 0.79 points from 0.28 per cent in 1981 to 1.07 per cent in 2005, the chained dollar share rose 1.33 points from 0.13 per cent to 1.46 per cent (Table 10).

ICT Capital Stock

Current dollar estimates

In 2005, total ICT net capital stock in the total economy in Canada, based on geometric depreciation, was $92.2 billion in current dollars, up more than six-fold from 16.0 billion in 1980 (Table 1). The share of the ICT capital stock in the total non-residential business sector capital stock has risen steadily, from 2.68 per cent in 1980 to 4.31 per cent in 2005 (Chart 6).

Chart 6: Current Dollar ICT Capital Stock/Total Non-Residential Capital Stock Shares by Component in the Total Economy in Canada, 1980-2005



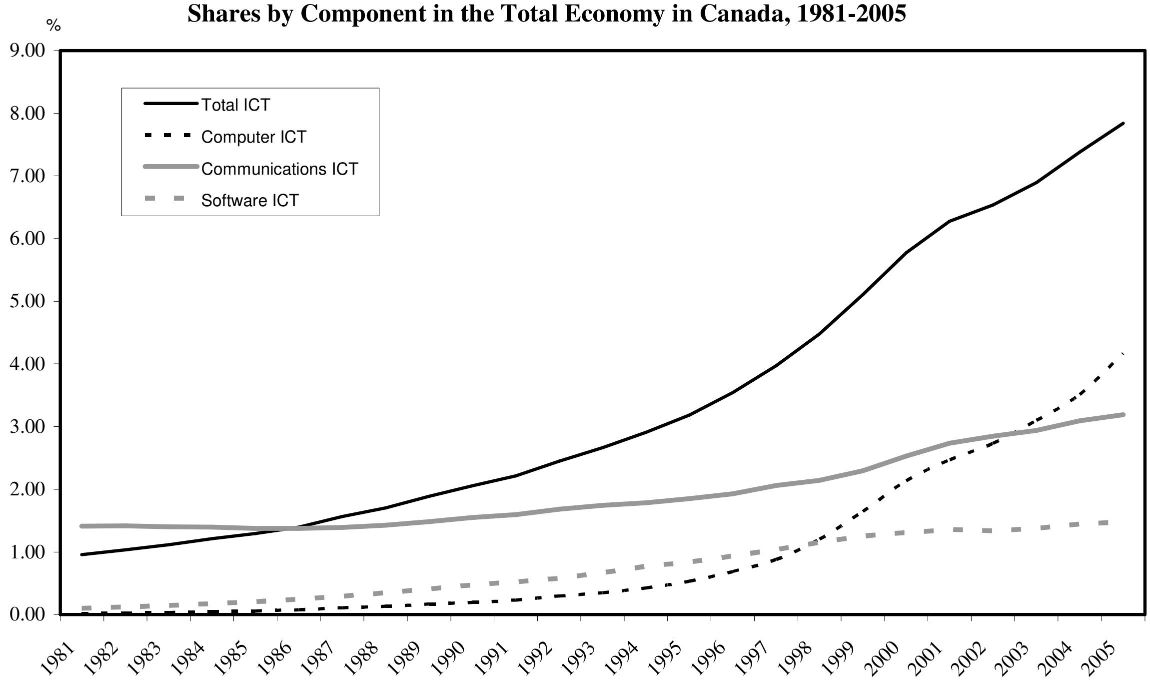
Source : Table 1 to Table 4

Depreciation rates differ significantly among ICT investment components. Based on the formula that depreciation equals the absolute change in the capital stock between years plus investment, the depreciation rate in 2005 was 62.9 per cent for software, 51.5 per cent for computers, and 19.7 per cent for communications. Consequently, the relative importance of the three ICT components in the capital stock will differ markedly from that for ICT investment. Instead of software being the most important ICT component, communications assumes that role. In 2005, the communication capital stock accounted for 2.21 per cent of the total non-residential capital, about one half the overall ICT capital share of 4.31 per cent. Software followed in importance at 1.15 percent, with computers at 0.95 per cent. Over the 1980-2005 period, the share of software in the total capital stock increased the most, up 0.94 points from 0.21 per cent in 1980 followed by computers, up 0.57 points from 0.39 per cent in 1980, and finally communications, up only 0.12 points from 2.09 in 1980.

Chained dollar estimates

Because of the fall in the relative prices of ICT capital, chained dollar trends in the ICT capital stock differ markedly from that of current dollar trends. The ICT net capital stock for the total economy was $146.8 billion 1997 dollars in 2005, up 19-fold from $7.8 billion in 1980 (Table 6). The share of the real ICT capital in total non-residential capital rose nearly nine-fold from 0.84 per cent in 1980 to 7.84 per cent in 2005 (Chart 7).

Chart 7: Chained Dollar ICT Capital Stock/Total Non-Residential Capital Stock Shares by Component in the Total Economy in Canada, 1981-2005



Source : Table 7 to Table 10.

All three ICT capital components witnessed big increases in their share of the total real capital stock The largest was the computer capital stock, which rose from virtually nothing (0.01 per cent in 1980) to 4.17 per cent of the total capital stock in 2005 (Table 8 and Chart 7). This extraordinary development was due to the amazing 16.9 average annual fall in the price of the computer capital stock between 1980 and 2005 (Table 11). The communications capital stock rose from 1.38 per cent in 1980 to 3.19 in 2005 (Table 9) while the software capital stock increased from 0.10 per cent in 1981 (data for 1980 are not available) to 1.48 per cent in 2005 (Table 7).

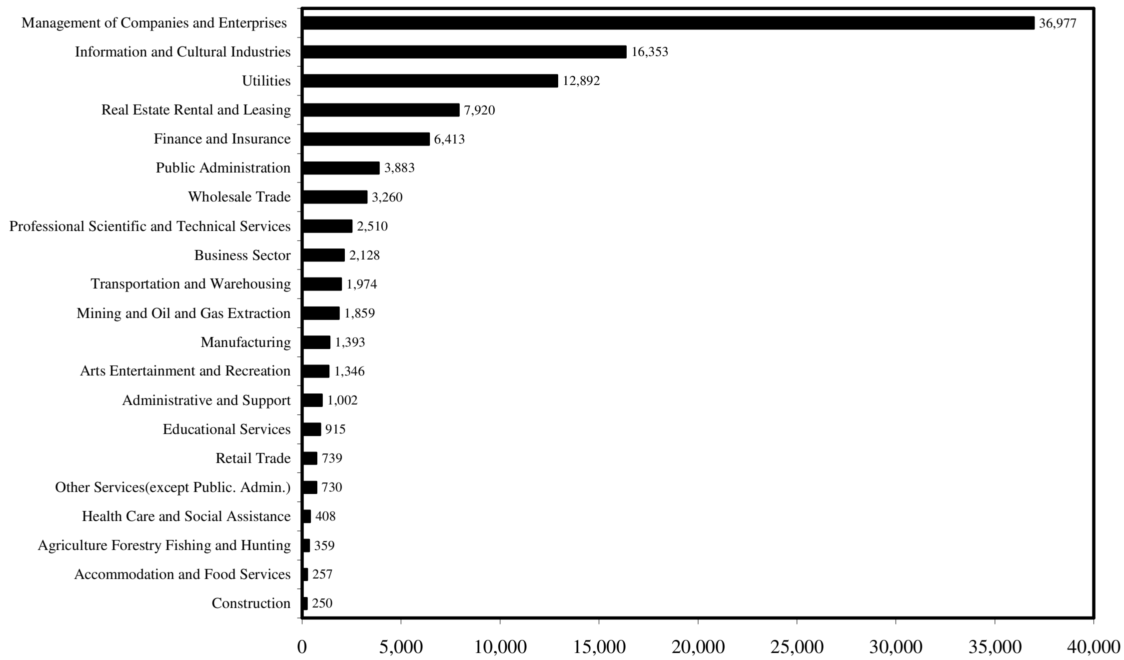
ICT Investment Per Worker

Current dollar estimates

Table 12 presents estimates of investment intensity, that is investment per worker, for total ICT capital, computers, communications equipment, and software in 2005 for the 20 two-digit industries in Canada based on the North American Industry Classification System (NAICS). In 2005, ICT investment per worker in the business sector in Canada averaged $2,128 current dollars. Consistent with the overall distribution of ICT investment among the three ICT components, software investment was largest at $911 per worker, followed by computer investment ($650 per worker), and communication investment ($567 per worker). In other words, software roughly accounts for around one half of total ICT per worker, while computers and communications equipment each represent around one quarter.

A number of observations can be made on ICT investment intensity by industry.

Chart 8: Total ICT Investment Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

Source : Table 12

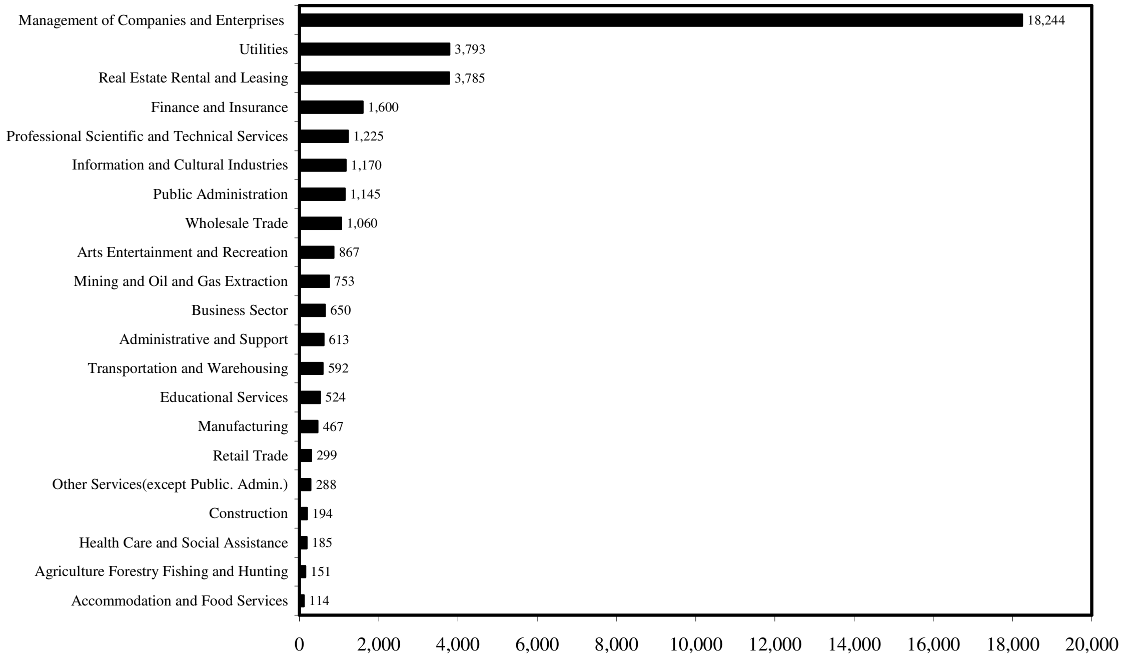
- There is great divergence in the use of ICT among industries in Canada. ICT investment per worker in the most ICT investment-intensive industry is more than 150 times that of the least ICT intensive industry (Chart 8). This suggests that ICT underinvestment, if it exists, may be sector-specific as one might expect that certain types of ICT would have applications in all industries.

- The most ICT investment intensive industry in Canada in 2005 was management of companies and enterprises, with ICT investment valued at $36,977 current dollars per worker. This is a very small unrepresentative industry, consisting largely of head offices, with minimal employment of only 2,500. This industry was also the most computer and software investment intensive (Chart 9 and Chart 10). The information and cultural industry was by far the most communication investment intensive.

- The second and third most ICT investment intensive industries were information and cultural industries ($16,353), which includes telecommunications and utilities ($12,892), with the first driven by very high ICT communications investment per worker (Chart 11).

- The least ICT investment intensive industry was construction with ICT investment of only $250 per worker. It was followed by accommodation and food services($257); agriculture, forestry, fishing and hunting ($359); and heath care and social assistance ($408).

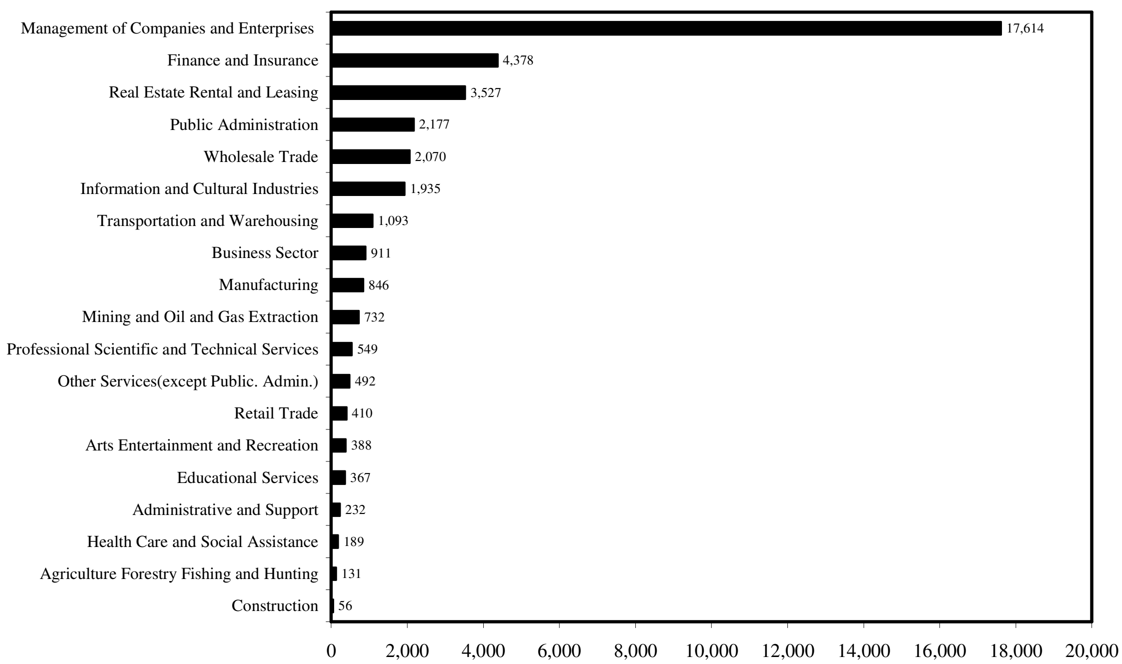
Chart 9: Computer ICT Investment Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

Source : Table 12

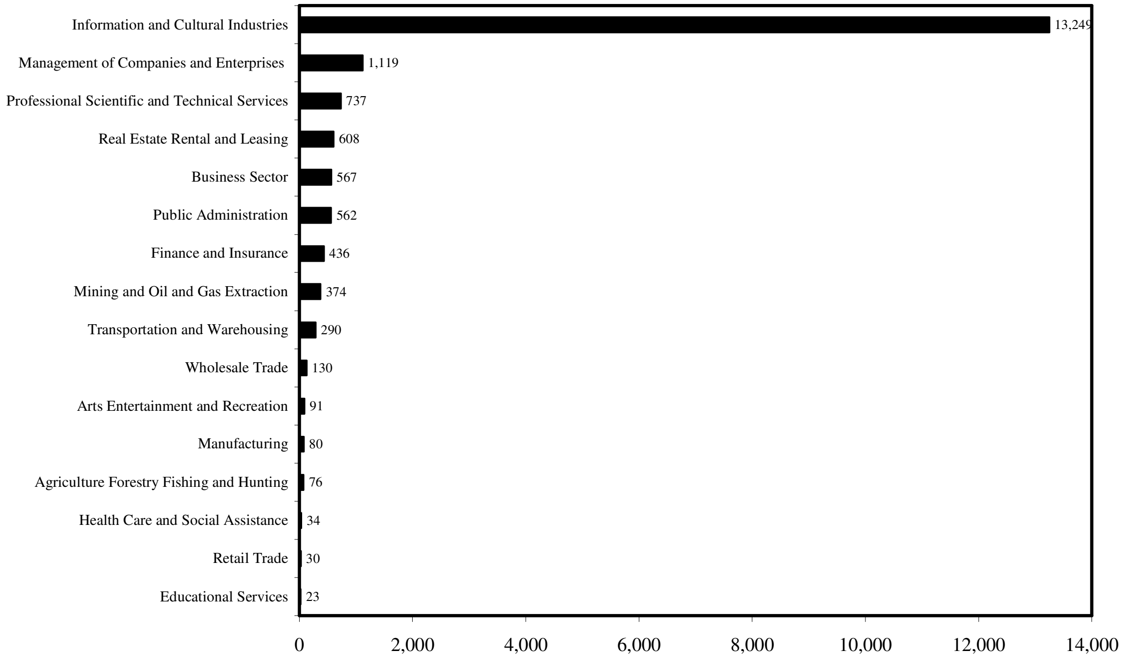
Chart 10: Software ICT Investment Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

Source : Table 12

Chart 11: Communications ICT Investment Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

Source : Table 12

ICT Capital Per Worker

<u>Current dollar estimates</u>

Table 12 also presents current dollar estimates of capital intensity for total ICT capital, computers, communications equipment, and software in 2005 for the 20 two-digit industries in Canada based on the North American Industry Classification System (NAICS). In 2005, ICT capital per worker in the business sector in Canada averaged $6,007 current dollars. Communications equipment was largest component at $3,250 per worker, followed by software ($1,518 per worker), and computers ($1,240 per worker). Thus communications equipment accounts for about one half of total business sector ICT capital per worker and computers and software each one quarter. The relative importance of ICT components for ICT capital differs from that for ICT investment because of the rapid depreciation rate for software and the slower depreciation rate for communications equipment.

A number of observations can be made on the distribution by industry of ICT capital.

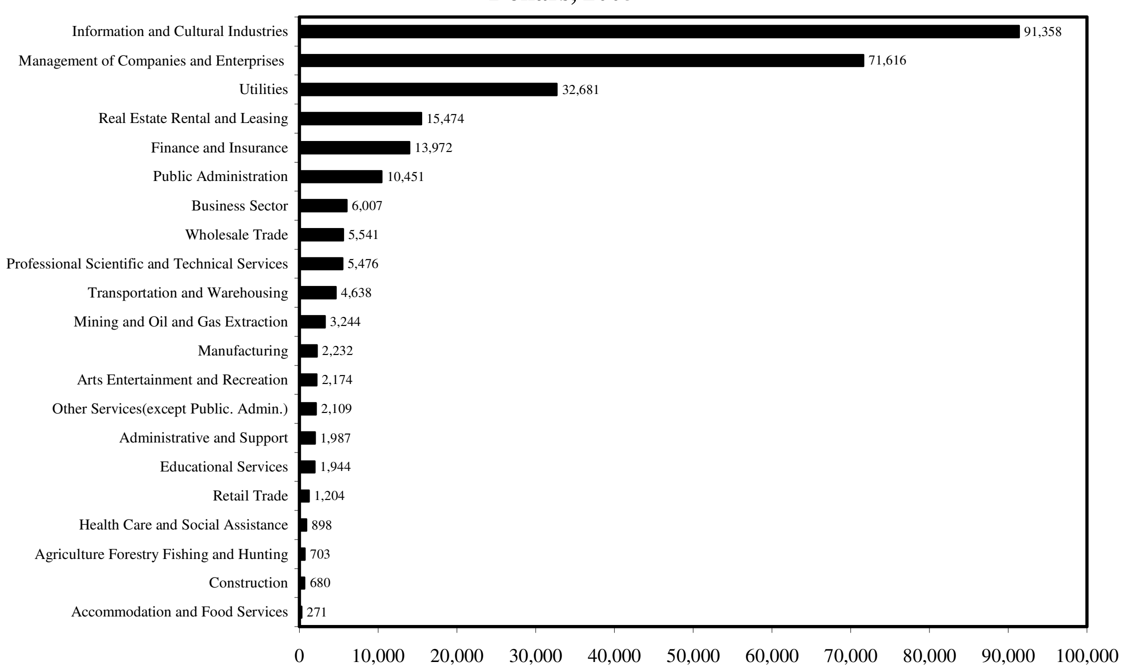
- There is even greater divergence in ICT capital intensity among industries than there is for ICT investment. ICT capital per worker in the most ICT capital-intensive industry is more than 300 times that of the least ICT intensive industry (Chart 12). This again suggests that ICT underinvestment, if it exists, may be sector-specific.

- The most ICT capital intensive industry in Canada in 2005 was information and cultural industries, with ICT capital valued at $91,358 per worker in current Canadian dollars. Communications capital, at $85,029 per worker, accounted for over 90 per cent of the total ICT capital in this industry (Chart 13).

- The second and third most ICT capital intensive industries were management of companies and enterprises ($71,616 per worker), with about half of is capital stock in computers (Chart 14) and half in software (Chart 15); and utilities ($32,681).

- The least ICT capital intensive industry was accommodation and food services with ICT capital of only $271 per worker. It was followed by construction ($680); agriculture, forestry, fishing and hunting($703); and heath care and social assistance ($898).

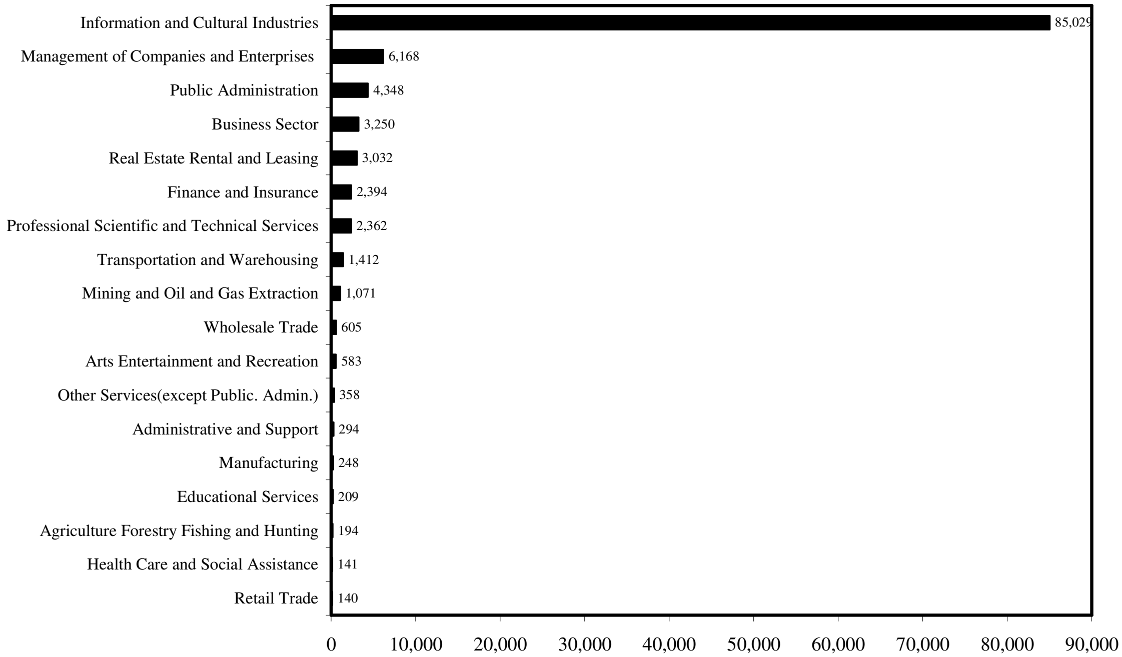
Chart 12: Total ICT Capital Stock Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

Source : Table 12

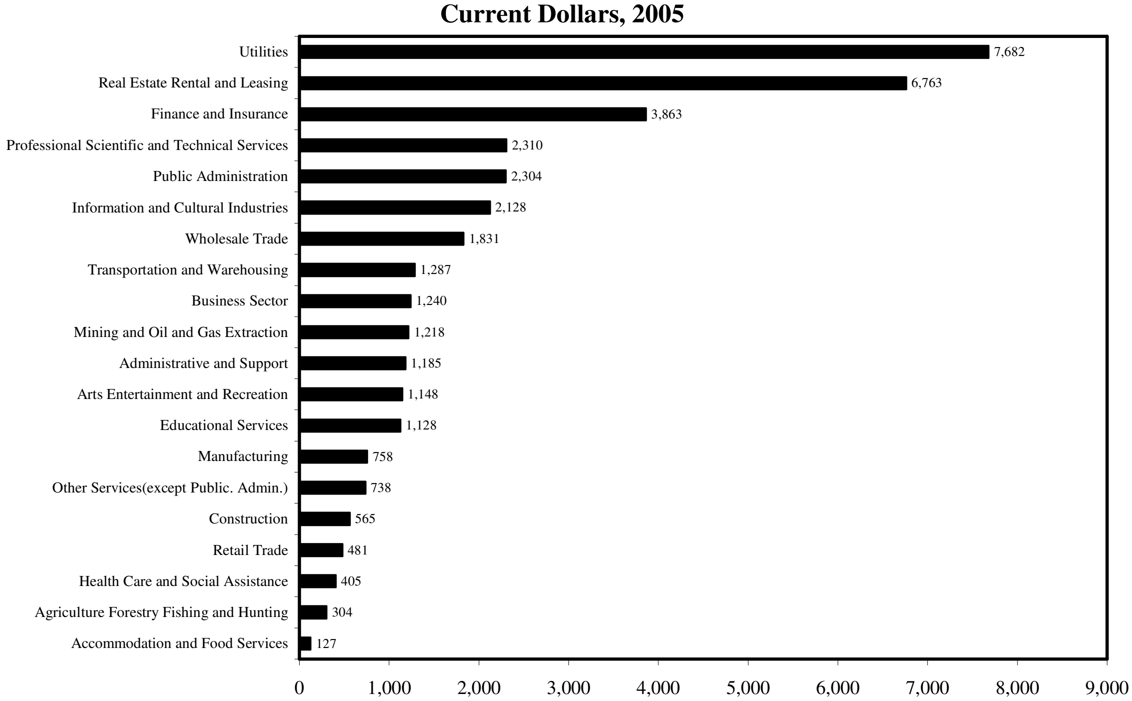
Chart 13: Communications ICT Capital Stock Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

Source : Table 12

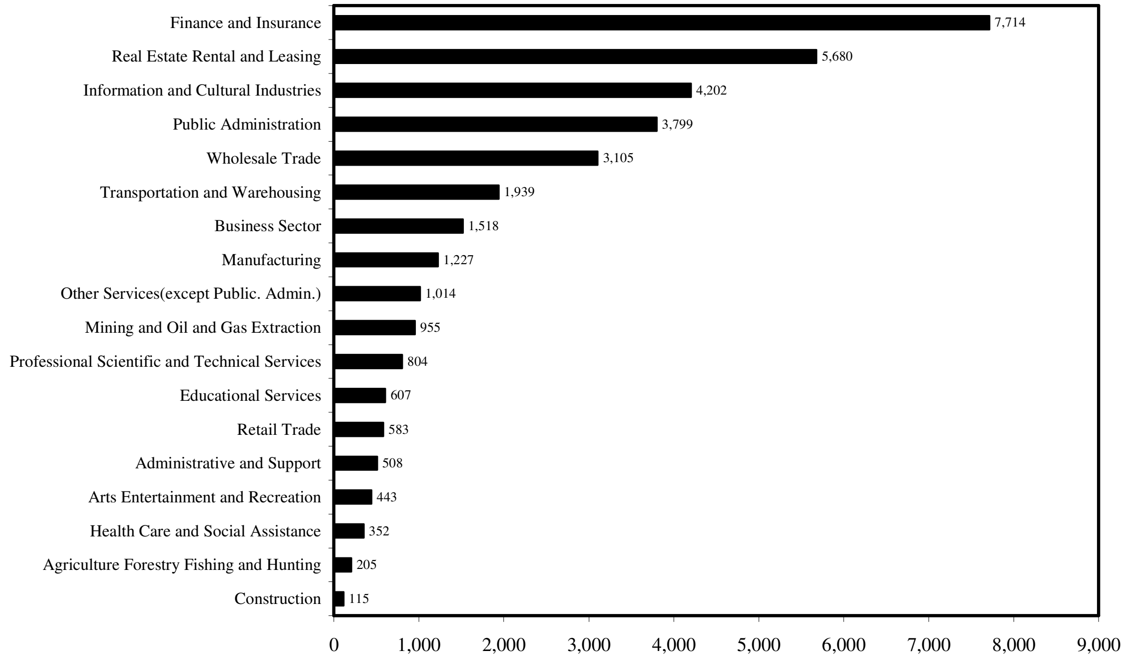
Chart 14: Computer ICT Capital Stock Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

Source : Table 12

Chart 15: Software ICT Capital Stock Per Worker by Industry, Canada, Current Dollars, 2005



Note : Industries without a value are not shown.

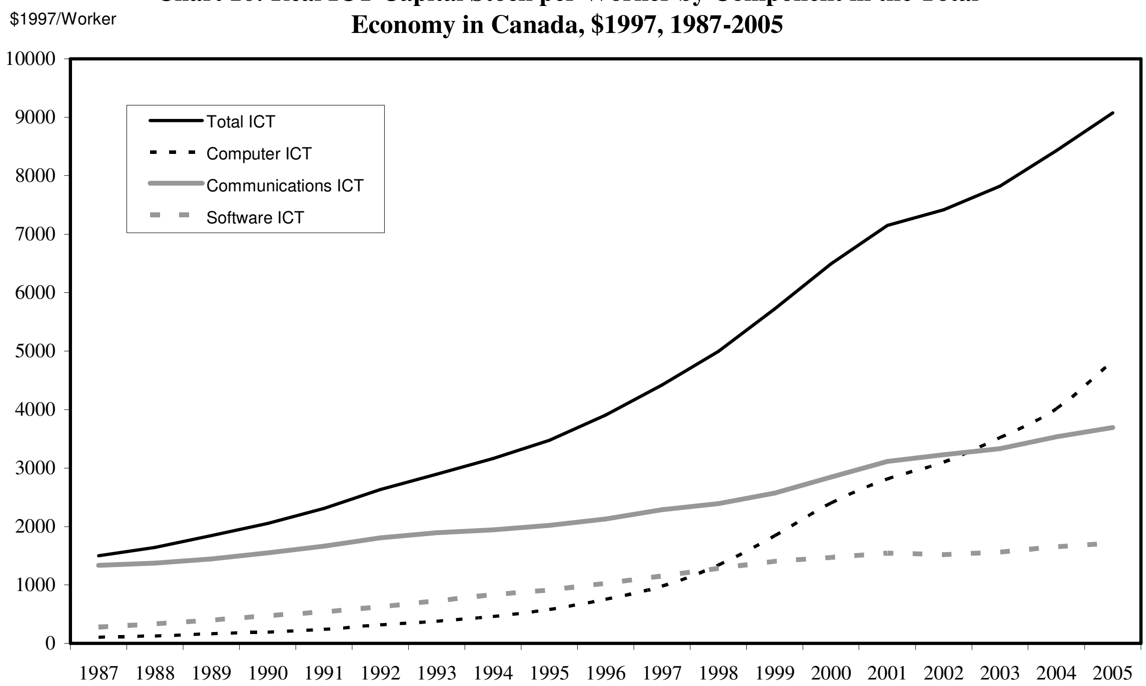
Source : Table 12

Chained dollar estimates

To track trends in capital intensity over time, real or chained dollar estimates of ICT capital per worker must be used to account for changes in the prices of capital goods. In 2005, total ICT net capital stock per worker in the total economy in Canada, based on geometric depreciation, was $9,079 in chained 1997 dollars, up more than six-fold from $1,497 billion in 1987 (Table 13 and Chart 16). Over the 1987-2005 period, growth in real ICT capital stock per worker considerably outpaced growth in real total capital stock per worker, increasing at an average annual rate of 10.5 per cent compared to only 1.07 per cent per year. While in 1987 the average worker had only 1.56 percent of its capital stock in the form of ICT, this share climbed steadily and reached 7.84 per cent in 2005 (Table 13).

The large increase in real ICT capital intensity was mainly driven by the rise of real computer ICT capital stock per worker, which increased from $106 in 1987 to $4,829 in 2005, an average annual growth rate of 23.6 per cent (Chart 16). Increased computer capital stock per worker accounted for almost half of the total increase in ICT capital stock per worker over the 1987-2005 period. Software also increased steadily, with software capital stock per worker rising an average of 10.6 per cent per year, from $280 in 1987 to $1,716 in 2005.

Chart 16: Real ICT Capital Stock per Worker by Component in the Total Economy in Canada, $1997, 1987-2005



Source : Table 13

Communications ICT per worker increased at an average pace of only 5.83 per cent per year from $1,333 in 1980 to $3,695 in 2005. This rate of growth was still much higher than the total capital per worker average growth of 1.07 per cent. However, because of its slower growth compared to the other two ICT components, communications capital stock per worker went from representing 89.0 per cent of total ICT capital stock per worker in 1987 to only 40.7 per cent in 2005. Its relative importance in total ICT capital stock was lessened by the stellar growth in computer capital stock per worker.

A number of observations can be made on the pattern of growth rates for real total ICT capital stock per worker across industries over the 1987-2005, the 1987-2000 and the 2000-2005 periods (Tables 14-17):

- Capital intensity in management of companies and enterprises grew much faster than all other industries, at 89.4 per cent per year (Chart 17). However, this industry is small, employing only about 2,500 workers.

- Information and cultural industries, including telecommunications, saw capital intensity grow only 6.0 per cent per year over the 1987-2005 period, slower than almost every industry (Table 14). This dampened growth in ICT capital stock per worker at the total economy level,.

- Almost all industries experienced slower growth in ICT capital stock per worker over the 2000-2005 period compared to the 1987-2000 period

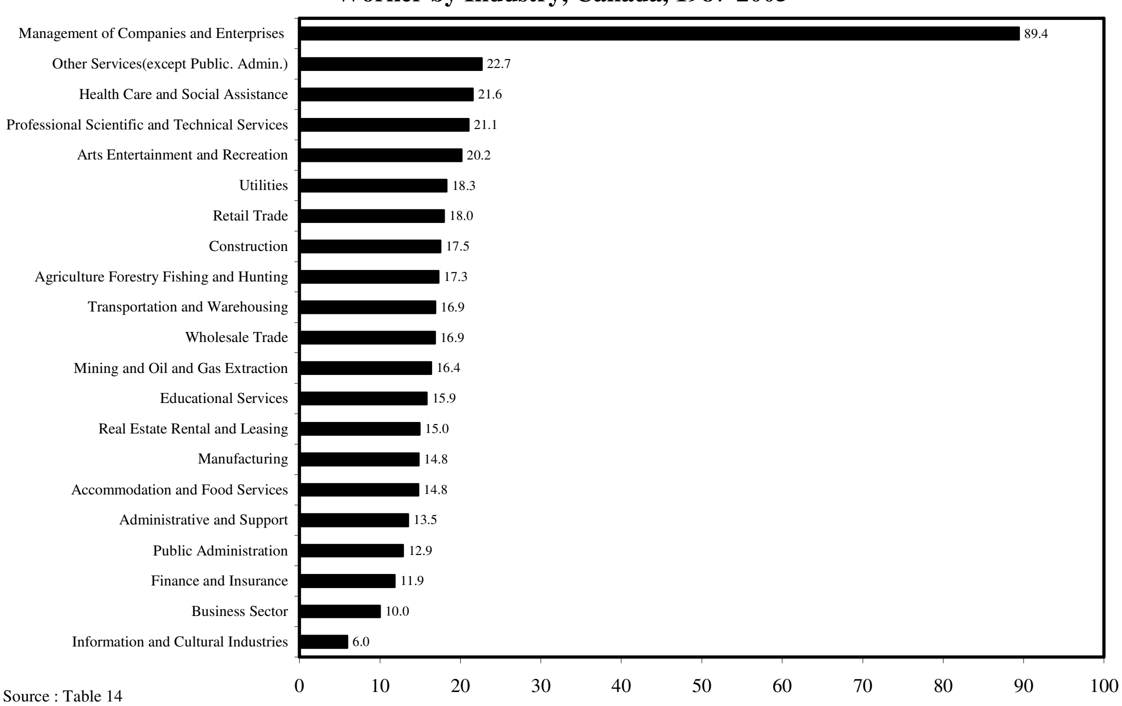
(Table 14). The two exceptions were mining and oil and gas extraction and accommodation and food services.

- Computer capital stock per worker increased at an average rate of 23.6 per cent between 1987 and 2005, with no industry experiencing an annual growth rate below 18 per cent (Table 15 and Chart 18). However, the average rate of growth halved from 27.1 per cent for the 1987-2000 period to 15.0 for the 2000-2005 period.

- While communications capital stock per worker increased in all industries between 1987 and 2000, it decreased between 2000 and 2005 in arts entertainment and recreation industry (Table 16 and Chart 19). Over the 1987-2005 period, the weakest growth in communications capital stock per worker was in the administrative and support industries (1.1 per cent per year) while wholesale trade grew the fastest (21.0 per cent per year) (Chart 19).

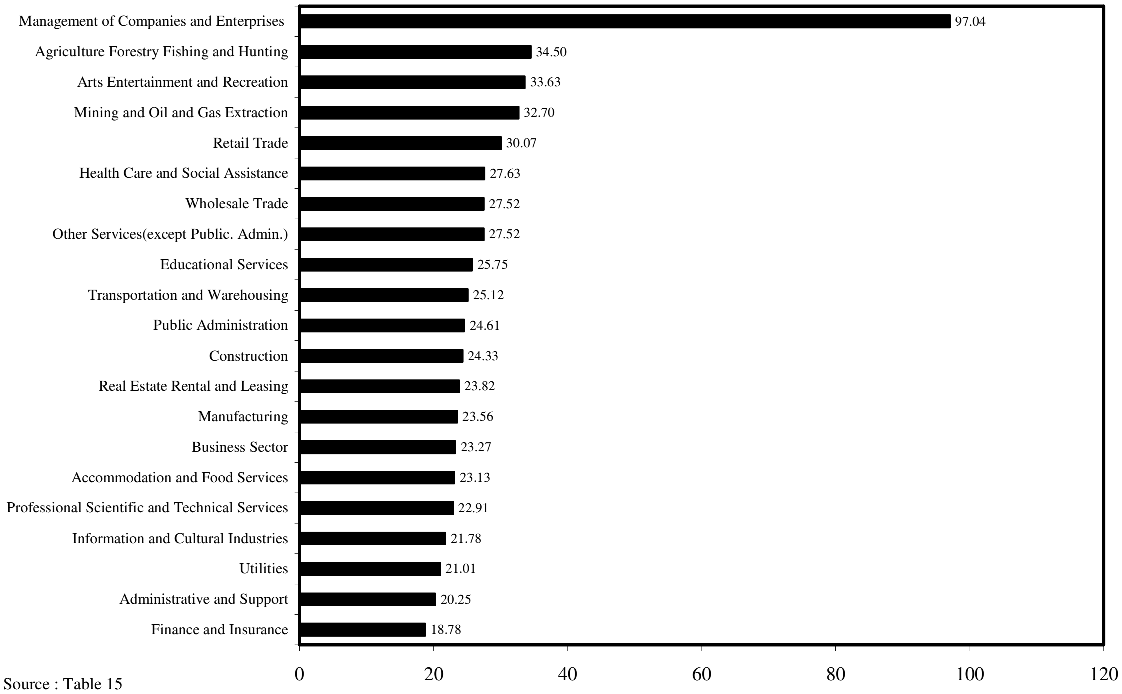
- The pace of growth in software capital stock per worker fell considerably in the 2000-2005 period (3.1 per cent), to about a quarter of its average growth in the 1987-2000 period (13.6 per cent) (Table 17). Over the 1987-2005 period, management of companies and enterprises grew the fastest with an average annual growth rate of 83.7 per cent while construction, growing at a pace of 3.4 per cent per year, was the slowest (Chart 20).

Chart 17: Average Annual Growth Rate in Real Total ICT Capital Stock per Worker by Industry, Canada, 1987-2005



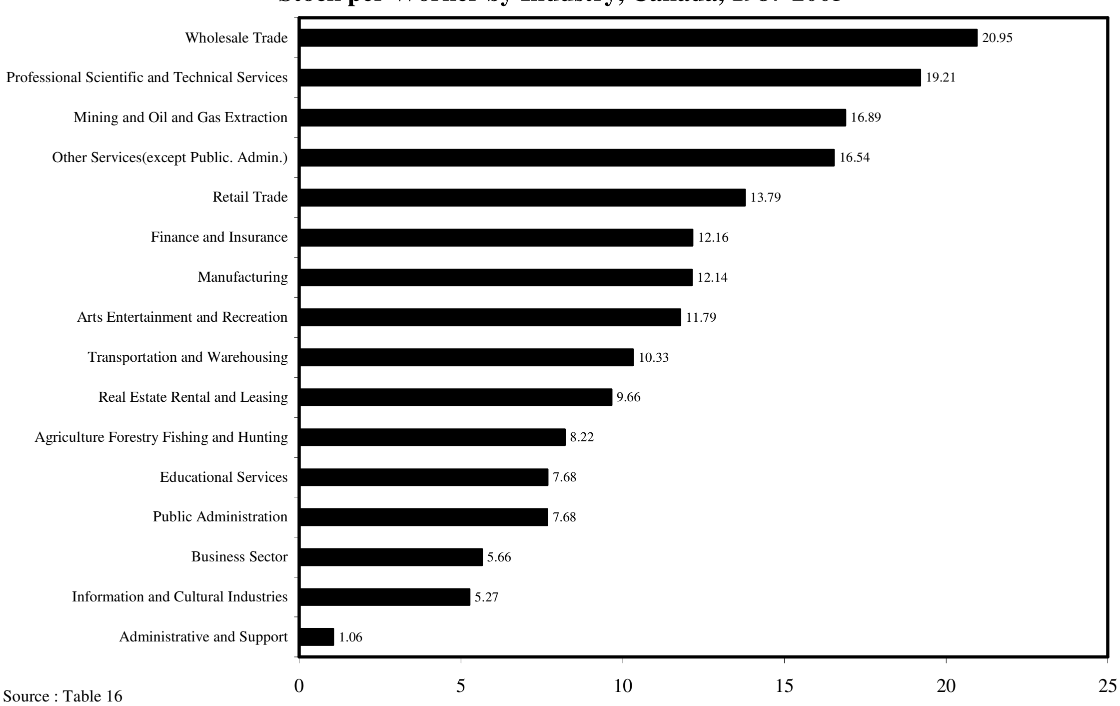
Source : Table 14

Chart 18: Average Annual Growth Rate in Real Computer ICT Capital Stock per Worker by Industry, Canada, 1987-2005



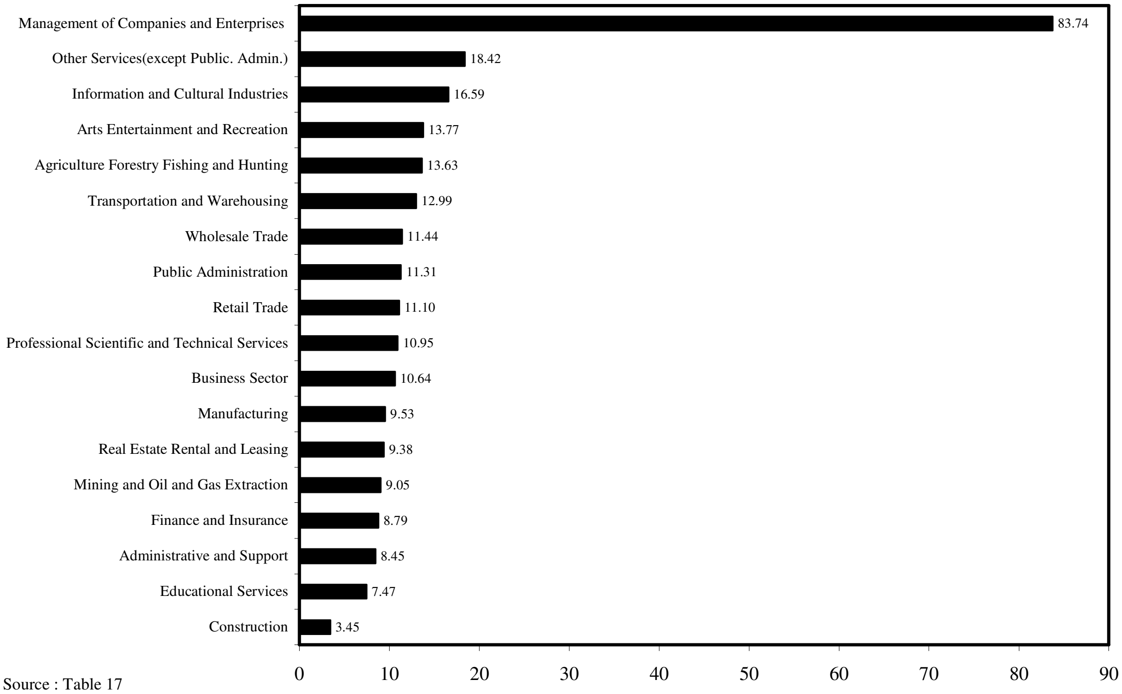
Source : Table 15

Chart 19: Average Annual Growth Rate in Real Communications ICT Capital Stock per Worker by Industry, Canada, 1987-2005



Source : Table 16

Chart 20: Average Annual Growth Rate in Real Software ICT Capital Stock per Worker by Industry, Canada, 1987-2005



Source : Table 17

Part Two: General Discussion of the Relationship Between ICT Investment and Productivity

In the consultation paper released in June 2005, the Telecommunications Policy Review Panel put forward a number of questions on the relationship between ICT investment and productivity. This part of the report provides a general discussion of the relationship between ICT investment and productivity motivated by the questions in the consultation paper.

Relationship Between ICT Investment and Productivity

In general, ICT investment has a positive effect on productivity growth (the link between ICT investment and productivity levels is another less important issue and not discussed here), but the relationship is complex. Different aspects of the ICT investment-productivity nexus are outlined and discussed below.

<u>Labour productivity versus total factor productivity and implications for the ICT investment-productivity relationship</u>

The relationship between ICT investment and productivity growth, depends on the measure of productivity used, that is labour or total factor productivity (also called multifactor productivity). ICT investment is defined to include computers, telecommunications equipment, and software. Labour productivity is defined as the ratio of real output, measured as either value added or gross output, to labour input, measured as either hours worked or persons employed.

Total factor productivity (TFP) is defined as the ratio of output to all inputs used in the production process. Some TFP measures are based on only the primary inputs of labour and capital, while other TFP measures expand the definition of inputs to include purchased services and intermediate inputs such as raw materials and energy. TFP growth (a measure of TFP in absolute level is problematic because of the difficulty of aggregating physical inputs (e.g. hours of labour, tons of steel) measured in different units) is defined as the differences between the growth rate of real output and an index of total inputs. This latter index is constructed by weighting the growth rates of the individual inputs by their income share, which is assumed to represent the value of their marginal product or contribution to output. TFP growth is basically labor productivity growth adjusted for changes in capital intensity and is sometimes called a "measure of our ignorance" as it includes the effect of economies of scale and scope, capacity utilization, measurement error, technological change, and other factors.

In a two factor of production (capital and labour) model, growth accounting methodology allows one to decompose labour productivity growth into two components: changes in capital intensity or the capital/labour ratio, and changes in TFP. If the capital/labour ratio remains constant over time, labour productivity growth equals TFP growth. Historically, the capital/labour ratio has been increasing over time, meaning that labour productivity growth has exceeded TFP growth.

ICT investment affects labour productivity both through the capital intensity and the TFP channels. ICT investment increases the ICT capital stock and may increase capital intensity depending on labour input trends. If so, each worker will have more ICT capital to work with and will in principle be more productive. From a growth accounting perspective, the contribution to labour productivity growth of ICT capital is calculated by multiplying the rate of growth of the ICT capital/worker ratio by the income share of ICT capital in total value added.

An illustration may make this procedure more transparent. Assume that ICT capital represents one quarter of the value of the total capital stock and that capital's income share is 40 per cent. This makes the income share of ICT capital 10 per cent. If the growth rate of ICT capital intensity is 5 per cent per year, the absolute contribution of ICT capital to both output growth and labour productivity growth would be 0.5 per cent per year. The relative contribution to productivity growth is calculated by dividing the absolute contribution by the productivity growth. In this case, if labour productivity growth is 2 per cent, the relative contribution of ICT capital would be one quarter or 25 per cent (0.5/2).

In addition to the positive impact of ICT investment on labour productivity growth through the higher ICT capital intensity channel, ICT investment and capital stock can directly contribute to TFP growth and thereby to labour productivity growth. Thus, part of the contribution of ICT investment and capital to labour productivity growth is picked up by higher ICT capital intensity and part by technological progress to TFP growth. Unfortunately, there is no simple methodology to capture the total effect of ICT investment on labour productivity. Estimates of the contribution of ICT investment to TFP growth, and hence labour productivity growth, should be considered as very approximate in nature and as likely underestimating the true contribution of ICT to labour productivity growth as ICT investments are the carriers or manifestation of technological progress, the ultimate driver of labour productivity growth.

Limitations of the ICT Investment-Productivity Nexus Basic Framework

The basic growth accounting framework for the estimation of the impact of ICT investment on labour productivity growth, although extremely useful as a workhorse model to quantify the impact of ICT capital on productivity, has a number of serious limitations.

First, the impact of ICT investment on labour productivity growth may not occur in the same period in which the investment takes place due to lags. Leung (2004a,b) has found evidence that ICT investment appears to influence productivity several years later. These lags are related to the complementary investments in skills training that often need to be made for ICT to be effective, as stressed in the work by Brynjolfsson and Hitt (2000) discussed in the literature review in the next section of the report.

Second, the benefits of ICT investment on firm performance may go well beyond productivity increases and include quality improvements in products and services produced. For example, one might argue that the use of graphics or PowerPoint improves the quality of documents and presentations, but that these improvements are not reflected or captured in productivity statistics.

Third, ICT investments may be so small in magnitude that they have minimal effect on the capital stock, but represent such technological breakthroughs that they raise productivity significantly. In this case, such investments would have no effect on ICT capital intensity so their impact would not be picked up through this channel, but would have a major effect on TFP. But again because of the impossibility of providing quantitative estimates of the impact of the different drivers of TFP, the impact of ICT investments would not be captured here as well. Hence firm or industry case studies where the impact of specific ICT technologies as the internet can be directly linked to physical productivity gains (Litan and Rivlin, 2001) are needed. For example, the adoption of a software package that improved scheduling may result in less down time for workers, raising both labour and TFP growth. The documentation of such effects would be strong evidence of the productivity-augmenting impact of ICT investments.

Fourth, the net productivity gains from ICT investments may be less than expected because of the law of offset or the law of unintended consequences (Tenner, 1996). In other words, while ICT may indeed have important productivity-enhancing effects, they also may have non-trivial productivity-reducing effects, either directly or indirectly. The classic example is the impact of email on productivity. There is no doubt that email is a very effective communications tool. Yet it might be argued that many of the productivity gains arising from email have been eroded by spam and by the propagation of virus and worms that wreck havoc with computer systems. Equally, while most uses of computers are productivity-enhancing in a work environment, some uses such as playing computer games during work hours are productivity-reducing. Finally, cell phones may allow workers to keep in continuous contact, but the productivity benefits, as opposed to convenience, of such contact may be minimal or even negative.

Empirical Estimates for Canada of the Impact of ICT on Productivity by Industry

The literature review in the next part of the report surveys selected studies which have estimated the contribution of ICT investment to productivity growth at the aggregate level for Canada, the United States and OECD countries. The results are sensitive to a number of factors, including the period covered, the definition of the aggregate economy (total economy or business sector), the definition of ICT investment and capital stock (e.g. inclusion or exclusion of medical equipment such as MRIs), the ICT income share used, the use of capital services or capital stock for capital input, and estimation procedures for the real ICT capital stock (depreciation assumptions, choice of net or gross stock, as well as deflators used to convert current dollar ICT capital to chained dollars, among others).

Based on unpublished data provided by Statistics Canada, the Centre for the Study of Living Standards (CSLS) has calculated for this report the contributions in both absolute and relative terms of ICT capital and its components to labour productivity growth for the total economy and 20 two-digit NAICS industries for the 1987-2005 period (Table 19) and for the 1996-2000 (Table 20) and 2000-2005 (Table 21) sub-periods. The rates of growth of capital intensity for ICT capital and its three components for the total economy and 20 two-digit NAICS industries are reported in Table 14-17.

At the total economy level, the growth of ICT capital per worker contributed 0.19 percentage points to labour productivity growth over the 1987-2005 period, representing 15.3 per cent of the 1.25 per cent average annual increase in labour productivity (Table 19). This contribution was based on ICT capital intensity growth of 10.5 per cent per year over the 1987-2005 period and an average income share for ICT capital of 2 per cent.

The contribution of ICT capital intensity growth was positive for all industries, but ranged greatly, reflecting the great differences in the use of ICT capital across industries (Chart 12), and to a lesser extent reflecting industry differences in the rate of growth of ICT capital intensity (Table 14). Industries with very low ICT capital per worker, such as mining and oil and gas extraction, agriculture, forestry, fishing and hunting, and accommodation and food services had extremely low contributions of ICT capital to productivity growth (0.01-0.03 percentage points), while industries with high ICT capital per worker had very large contributions, such as 4 points in management of companies and enterprises, 1.95 points in professional, scientific and technical services, 1.19 points in information and cultural industries, and 1.15 points in finance and insurance (Table 19).

In terms of the three ICT components, computers made the largest contribution to labour productivity growth at the total economy level over the 1987-2005 period: 0.10 points, compared to 0.06 points for communications equipment, and 0.05 points for software. This is not surprising given that computer capital per worker increased at an amazing 23.6 per cent per year (Table 13), compared to 10.6 per cent for software and 5.8 per cent for communications.

In the 1996-2000 period, the contribution of ICT capital to labour productivity growth rose to 0.25 percentage points (Table 20), due to both more rapid ICT capital intensity growth, and a growing ICT income share associated with its growing importance. In 2000-2005, a period of much weaker labour productivity growth compared to the 1996-2000 period (Rao, Sharpe and Smith, 2005), the contribution of ICT capital fell to 0.13 percentage points per year because of a large fall-off in ICT capital intensity growth.

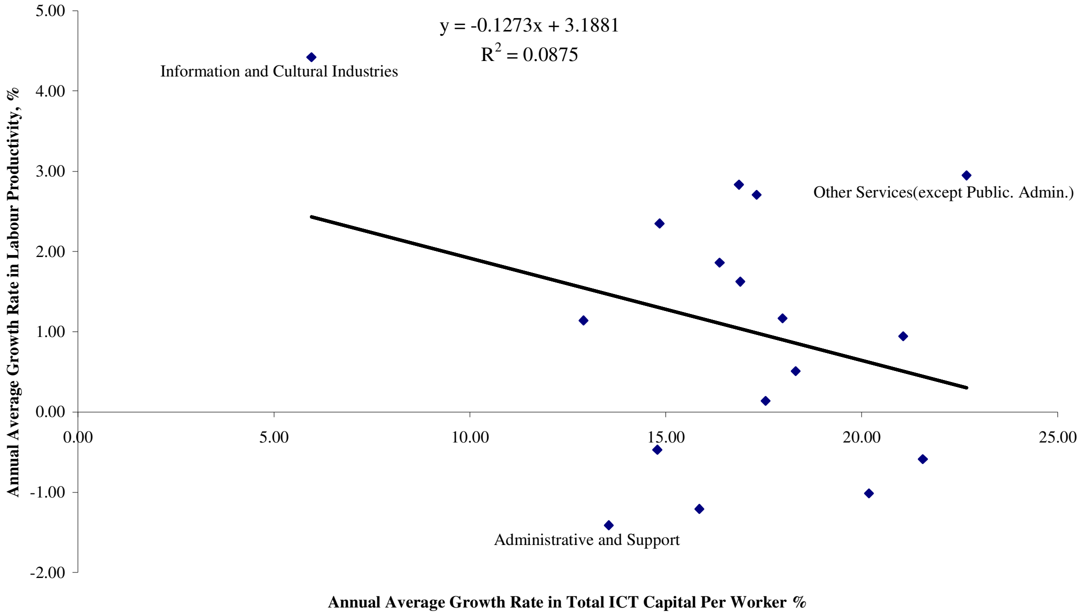
According to OECD growth accounting estimates (OECD, 2005), the contribution of ICT capital to total economy productivity growth in Canada over the 1995-03 period was 0.6 percentage points, up from 0.4 points in the 1990-95 period. Canada ranked 7th of out 19 OECD countries in the magnitude of the contribution. Australia was first at 0.9 points, followed by the United States at 0.8 points. This estimate is greater than that of the estimates above as it is based on capital services, not capital stock, which gives short-lived ICT assets a higher income share.

<u>The Relationship Between Capital Intensity Growth and Labour Productivity Growth at the Industry Level</u>

One might expect a positive relationship between labour productivity and the growth in ICT capital intensity. Industries with rapid capital intensity growth should experience rapid labour productivity growth and vice-versa. But scatter diagrams show that it is largely not the case.

At the industry level, our analysis does not show a straightforward relationship between growth in ICT capital intensity and labour productivity growth. In fact, the trend line in Chart 21 suggests a slightly negative relationship between total ICT capital intensity growth and labour productivity growth. However, the R^2, a measure of the goodness of fit which can range from 0 (no fit at all) to 1 (perfect fit), is very low at 0.088.

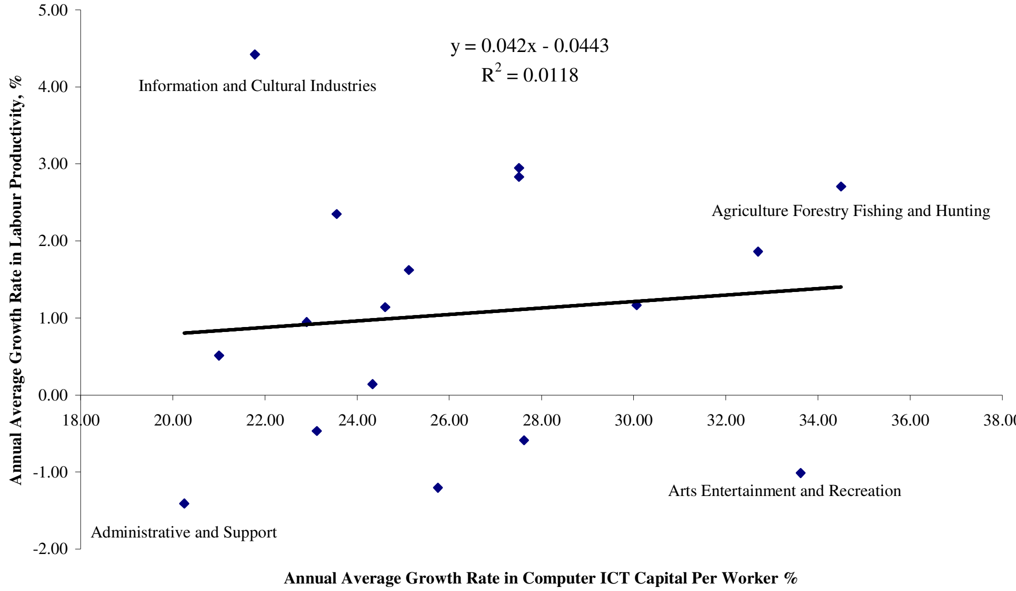
Chart 21 Relationship between Growth in Total ICT Capital Stock Per Worker and Growth in Labour Productivity across Industries, 1987-2005



Source: Table 27.

There appears to be no relationship between changes in computer capital intensity and labour productivity are (Chart 22). While information and cultural industries and administrative and support experienced similar computer capital intensity growth rate over the 1987-2005 period (21.8 and 20.3 per cent per year respectively), labour productivity in the former increased 4.4 per cent while it decreased 1.4 per cent in the latter.

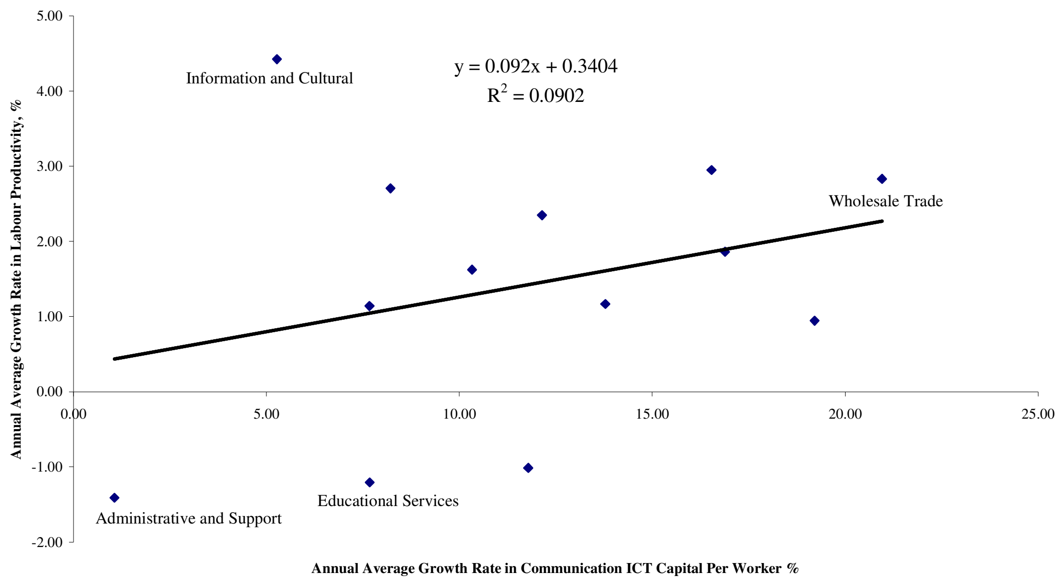
Chart 22 Relationship between Growth in Computer ICT Capital Stock Per Worker and Growth in Labour Productivity across Industries, 1987-2005



Source: Table 27.

The relationship between communication capital stock per worker and labour productivity is slightly more convincing (Chart 23). It is positively related and the fit (R^2 of 0.09) is slightly better than for total ICT capital intensity. However, many industries still do not fit well in the picture. For example, information and cultural industries (51) experienced the strongest productivity gain despite being the industry with the second lowest growth rate in capital intensity for the period.

Chart 23 Relationship between Growth in Communication ICT Capital Stock Per Worker and Growth in Labour Productivity across Industries, 1987-2005

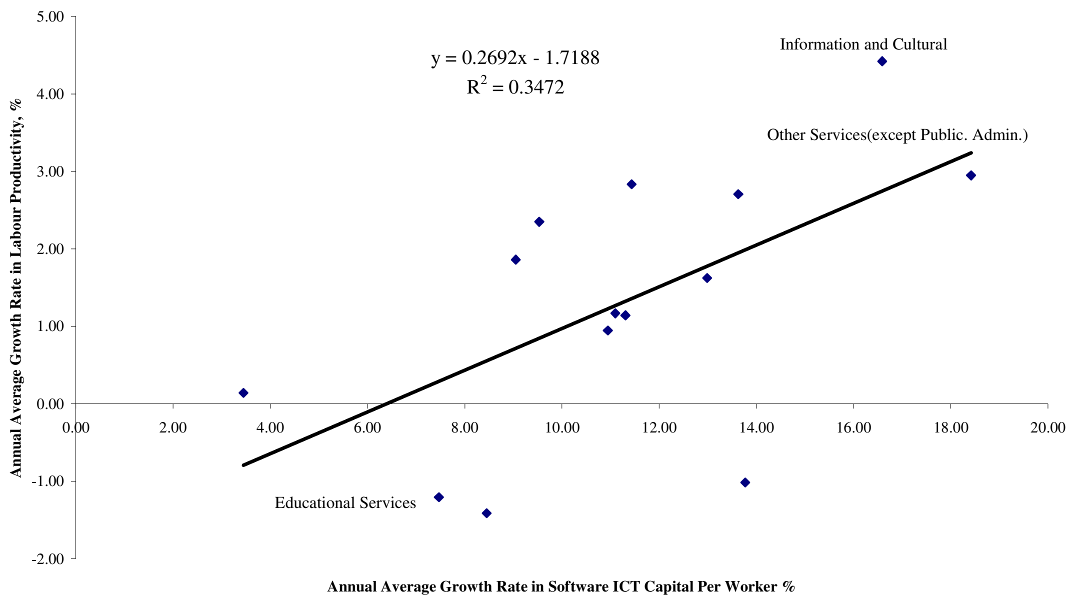


Source: Table 27.

Finally, the relationship between software intensity and labour productivity is surprisingly good. The fitted trend line suggests that, on average, a 1.0 per cent growth in software capital intensity will lead to a 0.3 per cent growth in labour productivity. Moreover, the fit is much better than for the other two components, with an R^2 of 0.35. Software capital intensity is the only component showing a consistent positive relationship to labour productivity across all industries (Chart 24).

In fact, the relationship between ICT capital intensity and labour productivity cannot be expected to be straightforward. Trends in labour productivity depend on many variables other than ICT capital intensity, such as the business cycle, R&D intensity, profitability, and industry specific input prices, hence a multivariate analysis is needed. Moreover, the beneficial effects of growth in ICT capital intensity are likely to be felt with a lag, which complicates the analysis. Finally, other forms of investment than ICT, the adoption of best practices, and differing competition pressures across industries can cast a shadow over the link between ICT capital intensity and labour productivity.

Chart 24 Relationship between Growth in Software ICT Capital Stock Per Worker and Growth in Labour Productivity across Industries, 1987-2005



Source: Table 27.

<u>Negative Consequences for Productivity from ICT Investment</u>

In principle, it is hard to see how ICT investment could have a negative impact on labour productivity growth, at least over the longer term. In the short term, problems associated with the introduction of computer systems and the elimination of bugs and glitches in the systems, could have a detrimental effect on productivity, but over the longer terms these should be eliminated.

While it is unlikely that the introduction of ICT will lead to a fall in productivity, the productivity benefits of ICT are often oversold, particularly by vendors (Landauer, 1995). Consequently, firms that have invested heavily in ICT may be disappointed in terms of their productivity gains, although there may be positive impacts on performance variables such as worker and consumer satisfaction, customer convenience, data and file access, information availability, and product quality which are not directly captured by conventional productivity measures.

Are Canadian businesses and governments under-investing in ICT?

There is no easy answer to the question of whether Canadian businesses under-invest in ICT. Economic theory shows that in an economy characterized by perfectly competitive markets, perfect knowledge and no externalities in production and consumption, economic actors such as firms and consumers will make decisions that maximize both profits and consumer utility. In such a world, there will be no under-investment in ICT as investment levels are by definition optimal. The real world of course differs from that in economic textbooks, with the extent of the perceived divergence varying from observer to observer. Free market economists tend to feel that the economic textbook models approximate the real world and that few interventions are needed to improve market outcomes. Economists with a more interventionist bent believe that the real world differs substantially from that of the economic textbooks, and that many interventions are needed to correct market failures.

Few economists make the argument that Canadian businesses under-invest in structures. More are willing to entertain the idea that businesses can under-invest in machinery and equipment and ICT. To male a case that Canadian businesses under-invest in ICT, one must argue that risk-adjusted private rates of return from such investment are greater than businesses expected due to imperfect information or other factors, or that the social rate of return from such investments exceeds the private rate of return because of externalities.

For example, Tarek Harchaoui and Faouzi Tarkhani (2004) from Statistics Canada, using econometric techniques, concluded that there were important externalities associated with information technologies in the United States flowing from that country's leadership in the IT area, but that this was not the case in Canada.

A recent literature survey by Aled ab Iorwerth (2005), a Finance Canada economist, concluded that because of the need to cover the fixed costs of innovating, the price of machinery and equipment is higher than the marginal cost, resulting in underinvestment in machinery and equipment in competitive markets. The paper (page 3) argues that

> "A policy compatible with new growth theory is to have low prices for machinery and equipment, particularly those that embody or lead to new technologies. A policy environment that is not conducive to investment in innovative equipment would exacerbate the negative implication of pre-existing distortion in the prices of innovative equipment: prices already exceed marginal cost. A policy to mitigate this distortion tackles directly the market failure."

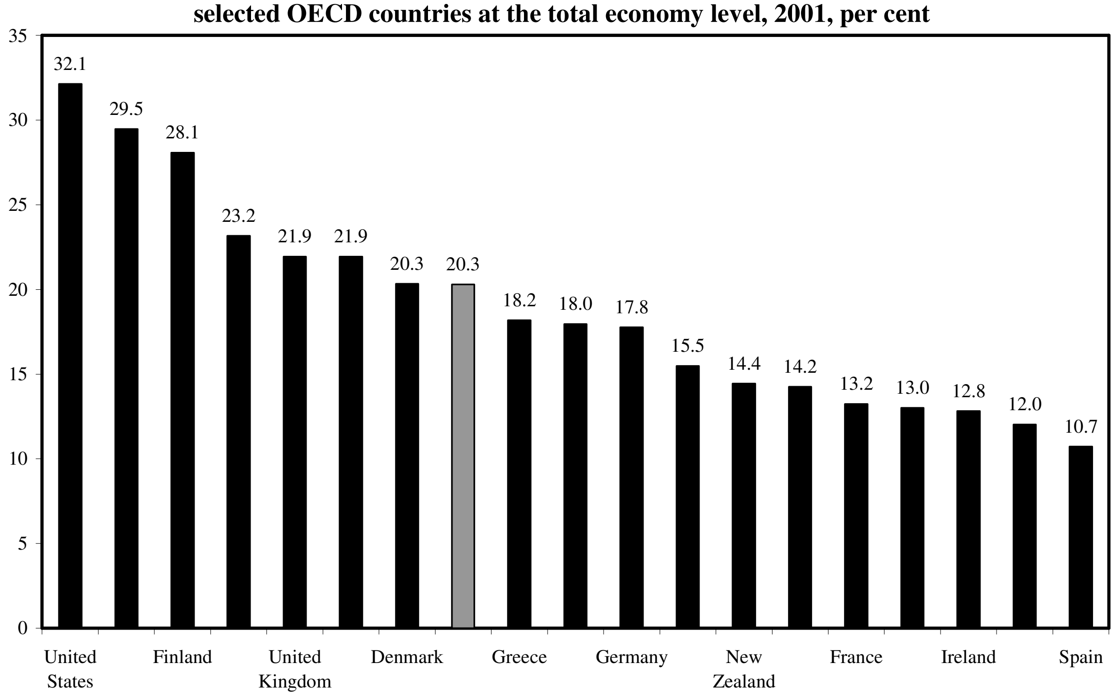
But externalities are often in the eye of the beholder. One example that is often given is broadband availability in rural communities. Businesses are not willing to make this investment because the rate of return would be insufficient or even negative. But such investments might improve economic prospects in these communities, although there is no easy way for the broadband provider to directly benefit from this increased level of economic activity. The failure of the investor to appropriate the social returns from his investments hence can lead to a socially sub-optimal level of investment and may justify government intervention in some form to promote investment. It is incumbent on proponents of the view that Canadian firms under-invest in ICT to identify the externalities that are associated with ICT investment, to give some indication of their importance, and their effect on social rates of return to ICT investments and on the divergence between private and social rates of return. Most economists consider the existing evidence that Canadian firms under-invest in ICT based on externalities not persuasive or convincing

Benchmarks for Gauging ICT Underinvestment

The most common argument that Canadian businesses under-invest in ICT comes from international data that shows ICT investment is less in Canada than in other countries. Chart 25 shows that in 2001 Canada ranked eighth among 19 OECD countries in the share of ICT investment in non-residential fixed capital formation. The leader was the United States, with an ICT investment share of over one and one half times that of Canada. The other countries whose ICT investment share exceeded that of Canada were in order Sweden, Finland, Australia, the United Kingdom, Belgium, and Denmark. These countries have enjoyed strong economic performance in recent years.

But not all the ten countries whose ICT investment share was less than that of Canada are economic laggards. The most obvious case is Ireland, a country that has experienced extremely robust economic and productivity growth in recent years but whose ICT investment share is only two-thirds that of Canada. The Netherlands, Germany, Italy, Japan, and France are also major industrial countries with lower ICT investment shares than Canada.

Chart 25: Shares of ICT investment in non-residential fixed capital formation in selected OECD countries at the total economy level, 2001, per cent



Source : Table 18

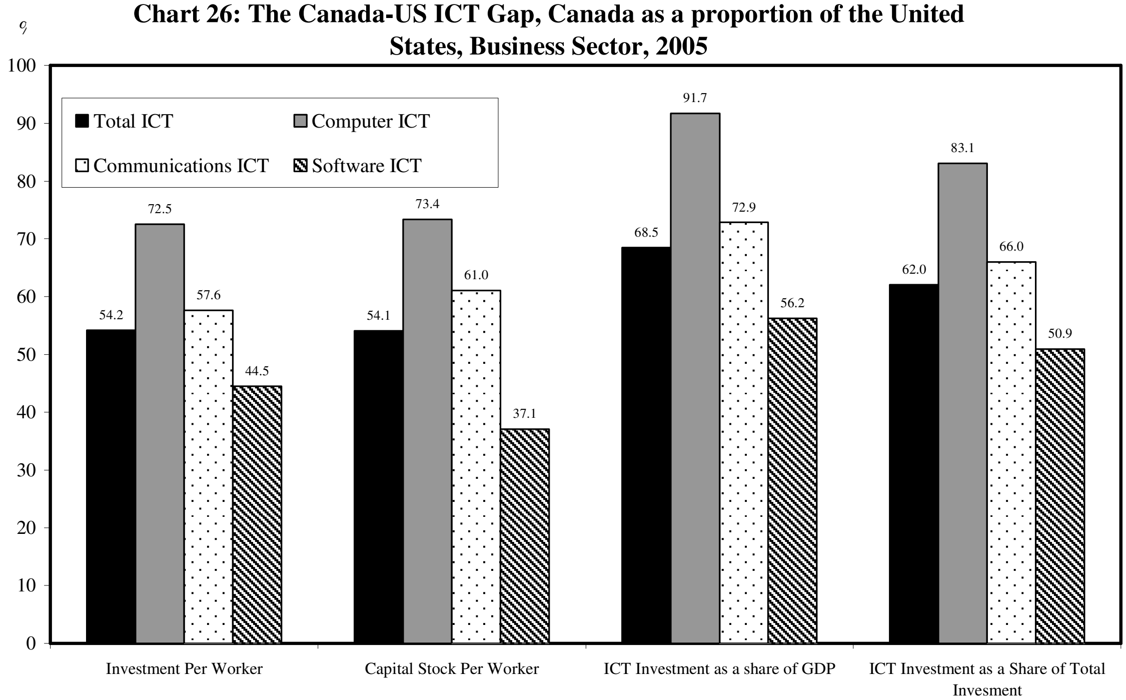
But the benchmark against which Canadian ICT investment is compared is not OECD countries, but the United States. In this regard, Canada appears to not measure up. There are three indicators or metrics that can be used to assess the adequacy of ICT investment:

- ICT investment as a share of total investment;
- ICT investment as a share of output or GDP; and
- ICT investment per worker.

In terms of the first indicator, Canada does poorly. In 2005, ICT investment in the Canadian business sector as a share of total business sector investment was 18.3 per cent, compared to 29.5 per cent in the United States, and thus represented only 62.0 percent of the US ICT/total investment proportion. The ICT investment share for all three ICT components was much lower in Canada, with computer ICT investment comprising 83.1 per cent of the US share, communications ICT 66.0 per cent, and software investment 50.9 per cent.

In terms of the second indicator, Canada performs slightly better, but still much worse than the United States. In 2005, ICT investment represented only 2.65 per cent of business sector GDP in Canada, compared to 3.87 per cent in the United States, that is 68.5 per cent of the U.S. level. Again, the ICT investment share for all three ICT components was lower in Canada, with computer ICT investment 91.7 per cent of the US share, communications ICT investment 72.9 per cent and software ICT investment 56.2 per cent.

Chart 26: The Canada-US ICT Gap, Canada as a proportion of the United States, Business Sector, 2005



Source: CSLS ICT Database.

The ICT investment/GDP share is directly related to the ICT investment/total investment share by the share of total investment in GDP. In 2005, the investment/GDP ratio in Canada was 14.5 per cent, which is 110.4 per cent of the 13.1 per cent US investment/GDP share. This higher investment share in Canada thus explains why ICT investment/GDP is relatively higher in Canada (68.5 per cent of that in the United States) than the ICT investment/total investment share (62.0 per cent).

For the third ICT investment adequacy indicator, Canada does the worst. In 2005, ICT investment per worker was $1,756 US dollars in Canada on a market exchange rate basis, 54.2 per cent of the US level of $3,242. Given that ICT goods are internationally traded, their purchasing power parity (PPP) is assumed to be close to the market exchange rate, which in 2005 was $0.83 US per Canadian dollar. In 2001, the last year for which an estimate of PPP for machinery and equipment investment was available, the difference between the PPP and the market exchange rate was only $0.03 ($0.68 for the PPP and $0.65 for the exchange rate). Moreover, for the 1992-2001 period, the machinery and equipment's PPP and the market exchange rate never diverged by more than $0.03. Again, the ICT investment per worker for all three ICT components was much lower in Canada, with computer ICT investment per worker 72.5 per cent of that in the United States, communications ICT investment 57.6 per cent and software ICT investment 44.5 per cent.

ICT investment per worker is directly related to the ICT investment/GDP ratio by the level of GDP per worker or labour productivity. In 2005, GDP per worker in Canada was $ 67,472 current US dollars at a PPP of $0.84. This was 80.5 per cent of the U.S. productivity level of $83,810. An adjustment for the ratio of the PPP (which is assumed to be the market exchange rate after 2001) of ICT investment relative to the GDP PPP (0.83/0.84 for 2005) must also be applied for consistency reasons (see Appendix 1 for a decomposition). These two factors hence explain why ICT investment per worker in Canada in 2005, at 54.2 per cent of that of the United States, was 14.3 points less than the Canada/US ICT investment/GDP share of 68.5 per cent.

Appendix 1 quantifies the four sources of the Canada-US gap in ICT capital intensity for the business sector in 2005. The most important factor, explaining 82.9 per cent of the gap is the lower share of total investment that goes to ICT in Canada. The second most important factor is the labour productivity gap, accounting for 29.1 per cent of the ICT capital intensity gap. The third most important factor is the lower PPP for ICT investment relative to the PPP for GDP, which explains 2.1 per cent of the gap. Finally, Canada's higher investment to GDP ratio contributes to closing 14.1 per cent of the gap.

A key issue is which of these gaps is most relevant for assessing ICT investment adequacy? From a narrow perspective, it might be argued that what counts is whether ICT investment is as important as a share of total investment as in other countries. This may be why the OECD uses the ICT investment/total investment share as its main indicator for international comparisons of ICT investment performance. By this criterion, Canada has a considerable shortfall with the United States (38.0 points), accounting for more than two-third of the ICT per worker gap.

But the ICT investment/total investment share may be a poor indicator of ICT adequacy when the overall investment/GDP share is lower than in other countries. In such a case, there may be shortfalls for all types of investment, not just ICT investment. If this is the case, then the ICT investment/total investment share does not capture the overall adequacy of the level of ICT investment relative to that in other countries. However, this is not the case in Canada, where total non-residential investment represents a slightly higher share of GDP (14.5 per cent) than it does in the United States (13.1 per cent). Thus, it appears that in Canada, it is specifically ICT investment that is lagging, not overall investment.

The third indicator, ICT investment per worker expressed in a common currency, is not used as much and may be less relevant than the first two indicators. As noted above, this measure is affected by productivity levels and by deviations in PPP between ICT and GDP. By definition, the relative gap in ICT investment per worker between a low productivity country and high productivity country will be greater for this measure than for the first two measures. Of course, since the absolute level of ICT capital per worker contributes to productivity, the higher level in the high productivity country may account for the higher productivity.

The Centre for the Study of Living Standards in 2005 undertook a research project for the Information Technology Association of Canada on the reasons Canadian firms spend less on ICT than their American counterparts (Sharpe, 2005 and CSLS 2005). The work includes the development of a large database for Canada-US ICT investment and capital stock comparisons by ICT component and by industry. A large number of hypotheses have been put forward for investigation in four broad areas: statistical and methodological differences including differences in ICT definitions and survey procedures; differences in economic structure such as industrial structure and the size distribution of firms; behavioral differences in perceptions of the importance of ICT and information lags; and differences in macro-economic variables such as ICT prices and tax rates. While no definitive explanation emerges, among the factors the research identifies as playing a role are industrial structure, the firm size distribution of employment, the price of labour compared to ICT investment goods, and the underestimation of ICT investment in official statistics.

Does the Relationship between ICT and Productivity Justify Government Support for ICT investment?

Given the importance of investment to the economy, government should in general pursue policies that support additional investment by the business sector. These policies include general framework policies such as low and stable inflation, sound fiscal policy, policies that ensure markets are competitive, and openness to international trade and foreign investment. They also include policies that directly affect investment such as maintaining low interest rates and low, but fair business taxes. In addition, government programs that provide information to firms to facilitate the adoption of advanced technologies and business practices should be encouraged.

But the question is whether ICT investment should receive preferential government treatment relative to other types of investments such as structures or non-ICT machinery and equipment. As the question implies, the answer depends on the relationship between ICT and productivity. As noted earlier , if positive externalities (that is benefits from ICT investments not directly captured by the firm) can be identified in terms of ICT investment over and beyond those found in other types of investments, then a case can be made on solid theoretical grounds for government to subsidize such investments. But evidence of such ICT-specific externalities for Canada is weak. ICT investment is no different than other types of machinery and equipment investment and does not merit special measures by government.

In contrast to this mainstream view Aled ab Iorwerth (2005), a Finance Canada economist provides a rationale for government intervention to support ICT investment. As noted above, he found that because of the need to cover the fixed costs of innovating, the price of machinery and equipment, including ICT, is higher than the marginal cost, resulting in underinvestment in machinery and equipment in competitive markets. He concluded that

> "Given that machinery and equipment may embody innovative ideas, the public economics literature suggests that governments must ensure that public policy does not unduly penalize the purchase of capital goods." (page 21)
>
> "Because innovative firms charge a price higher than marginal cost, the rates of innovating and diffusion will be low compared to a social optimum. A public policy that favours the adoption of machinery, which are more likely to embody innovations, can therefore be supported." (page 29)

Part Three: A Review of the Literature on ICT Investment and Productivity

This part of the report reviews selected literature on the impact of investment in ICT on productivity, with emphasis put on Canada. Since the second half of the 1990s, this subject has attracted much attention from researchers, especially because of the tremendous economic success the United States experienced since 1995. By no means is all the voluminous material on the topic of ICT and productivity reviewed. The focus is on some of the more important results and themes from the literature. For more comprehensive literature reviews see Mendes Rei (2004) and Dedrick et al. (2003).

The review begins with an overview of the mechanics of the relationship between ICT investment and productivity. This section will be more about the story than about the numbers. The second section of the review assesses the recent productivity and economic growth performance in Canada and some other OECD countries and how ICT investment contributed to this performance. Third, the difficult task of evaluating the optimality of the Canadian ICT investment rate and possible role of government will be based on studies of ICT contribution to MFP growth in OECD countries and in the United States. Finally, assuming a need for government involvement in fostering ICT investment to further improve productivity, some policy options presented in the literature will be reviewed in the final section.

ICT and Productivity: the Theory

Economic theory predicts that investing in capital goods will eventually lead to increases in labour productivity, as each worker has more or better tools to create value. But all capital goods were not created equal and some have more potential in helping improve productivity. Earlier technologies such as the steam engine and later the electrical engine, often called general purpose technologies (Helpman, 1998), allowed new ways of organizing work, a phenomenon that was labeled the industrial revolution, and consequently lead to surges in labour productivity.

The central thesis of the three studies reviewed in this section is that the computer is one of these general purpose technologies and that its main feature is to permit "complementary organizational investment," which changes the way production and distribution of goods is organized. The authors offer a clear exposition of how computers, and to a certain extent other information technologies, can have an impact on productivity growth. They present case studies to illustrate the mechanisms through which organizational changes improve labour productivity. This section highlights how the use of ICT capital leads to a reorganization of the firm, permitting changes in the relationship between the firm and its suppliers and customers.

Brynjolfsson and Hitt

Brynjolfsson and Hitt (2000) argue that one of the most important aspects of the use of ICT is that it requires a profound transformation of the firm in order for the productivity growth potential of ICT to be fully exploited and realized. Without organization changes, investment in ICT may not lead to cost reductions and higher productivity. For example, since ICT are much more flexible than earlier technologies, they allow workers to modify work practices. But the best practices that make the optimal use of the new capital are not always obvious. Brynjolfsson and Hitt report a case where workers were able to use the new equipment in exactly the same manner as the old equipment because of its flexibility, and by so doing eliminated the possibility of productivity improvements that the new technology offered.

ICT investment, to be worthwhile, requires firms to spend additional resources in training its workforce and testing new ways of organizing production. These costs constitute investments in complementary intangible assets which add to the total stock of capital, even though they are recorded as current business expenses (and hence not as investment) in national account estimates. Some studies cited by the authors report that the ratio of intangible assets to ICT assets could reach 10 to 1, suggesting that complementary investments in organizational assets are considerable (Brynjolfsson and Hitt, 2000:40).

The use of computers, including internet use, has modified the way businesses interact and manage their inventories. Before the generalization of ICT use, it was typical for large firms to integrate vertically to facilitate the coordination of the various stages of production by avoiding dependence on suppliers of inputs or intermediate goods. But since the 1980s, the decline in the costs of information exchange has changed this.

Brynjolfsson and Hitt give the example of supply networks in the hospital sector, where manually filled purchase orders were replaced by a computerized ordering system, linking electronically the hospitals to their suppliers. The suppliers gained a direct and almost instantaneous access to hospitals' inventories and could therefore manage stocks in an optimal manner while eliminating paperwork at the same time. Similar improvements in inventory management using automatic orders were introduced in retailing. These innovations lead to productivity improvements by reducing the amount of time spent on managing inventories and orders, as well as a better use of perishable inputs. The authors note that even General Motors, a classic example of a large vertically integrated firm, has started relying more on sub-contractors for the provision of inputs.

The use of the internet to market products has changed the way businesses deal with customers and consequently affected productivity by reducing the need for intermediaries such as wholesalers and sometimes distributors. The Dell computer company business strategy is a classic example of this phenomenon examined by Brynjolfsson and Hitt. ICT also makes markets more efficient because buyers have a speedy access to the latest developments from across the world. Gaining information about products, availability and prices is almost costless. This reinforces competition and allows consumers to make better buying decisions, leading to additional consumer surplus.

These types of benefits from ICT may not directly appear in national accounts statistics, but they reduce the time businesses spend making economic decisions, which increases productivity. These developments also mean that markets are much larger, since it is easier to sell anything anywhere in the world. Larger markets allow more specialization and economies of scale, which are key determinants of productivity.

Paul David

Paul David (2000) of Stanford University has made important contributions to the debate surrounding the role of ICT in productivity growth based on a historical perspective. He compares the contribution of computers to productivity growth with that of electricity. David points out that Solow's quip in 1987 that ICT was everywhere except in the productivity statistics, was elevated almost overnight into a leading economic puzzle of the late twentieth century. He notes that the acceleration of labour productivity growth in the United States since 1995 has diminished skepticism surrounding the role of ICT in productivity advance.

The paper examines analogous historical episodes involving the elaboration and the diffusion of other general-purpose technologies such as the electric dynamo. His approach rested upon the belief that "… we are in the midst of a complex, contingent, and temporally extended process of transition to a new, information-intensive techno-economic regime…"

Just as the beginning of the economic exploitation of the electric dynamo marked the end of the steam engine era, the advent of the digital economy seemed destined to result in the abandonment of many features of the so-called Fordism regime. This techno-economic transition involved profound changes in the production process, both in breadth and in depth. Those changes required decades rather than years, and while in process gave no guarantee of generating positive macroeconomic effects.

In fact, the rise of a new techno-economic framework could have disruptive and negative effects on performance due to the incompatibility between surviving elements of the previous economic order and the new framework. In that sense, the development of a digital information process disrupts as well as improves the technical efficiency of production. The specific nature of investment undertaken during the transition, adaptive in nature and experimental, was also likely to reduce the productivity of old assets. This could, in part, explain the slow trend rates of TFP growth in the transition period.

But with the passage of time, the exploitation of the new system should bring a strong resurgence in TFP growth. In particular, the development and exploitation of a new general-purpose system is associated with the coordination and the completion of a sequence of complementary changes in methods of work, production, business organization and institutional infrastructures. This should bring improvements in TFP growth performance.

According to some economists, the productivity slowdown and the productivity paradox both stem from mis-measurement problems. The lack of homogeneity in industry output, the heterogeneity in bundles of labor and capital services, the systematic overstatement of price increases and the understatement of both partial and total factor productivity improvements are elements that imply measurement biases.

In addition, the fast-pace introduction of new commodities, the increasing proliferation of goods and the broadening of the products also may be preventing statisticians from constructing accurate price indexes. Nevertheless, some progress had been made in resolving the paradox through the introduction of so-called hedonic price indexes, which indexes take account of quality changes and have boosted the growth of output and multifactor productivity in ICT-producing industries.

Moreover, the faster pace of product innovation and quality change has brought attention to a number of conceptual issues, such as the excess rates of return on computer capital. This phenomenon underscored a conceptual gap between task productivity measures, on the one hand, and measures of profitability and revenue productivity on the other hand. In fact, the rapid rate of anticipated depreciation of capital value, due to the high rate at which the price-performance ratio of new computer equipment fell, seemed to justify the existence of excess private returns to equalize firms' net private rates of return.

Along the same line, the presence of intangible investments, such as training programs and company reorganization programs linked to computerization, were found to be correlated to ICT intensity. Some economists argue that investments made by organizations and individuals in learning how to use new technologies should be included in the definition of the investment and hence included in GDP estimates. Taking these factors into account statistically leads to a substantial elimination of the apparent excess of the estimated returns on ICT capital as compared to the returns on other types of capital.

David introduces a regime transition hypothesis which emphasized the incremental technological, institutional, and social adjustments required for a new techno-economic system. Adaptations are neither costless nor instantaneous. The downside of general-purpose technologies (GPT), not only their new applications due to the transformation of the economy, should also be taken into consideration. He uses this framework to examine the computer productivity paradox.

Two initial phases of the transition dynamics that could contribute to slowing measured productivity growth were under scrutiny. The first, regarding the lags in the diffusion process involving a GPT, which suggested long delays in the acceleration of the productivity growth in the economy at large. This was based on the idea that productivity advances stemmed from the substitution of old production methods for newer ones. This dynamic process could be quite long. The second argued that resources tended to be directed, in earlier phases of the transition, to applying the innovation to provide new, qualitatively superior goods and services. The welfare gains of this allocation escaped being properly reflected in the measured output and productivity indexes.

David also highlighted new developments in productivity-enhancing computer technology. These developments included the growing range of purpose-built and task specific IT, the capabilities of advanced PCs as "network servers", and the development of a new class of organization-wide data-processing applications. Those developments will provide the infrastructure for task-oriented data acquisition and more accurate and detailed overviews of the material flows through the process, making it possible to use a greater part of the local area network in order to enhance the potential of the collective and cooperative forms of work organization.

National Research Council

A key cornerstone of the debate on the contribution of ICT to productivity in the 1990s was the report *Information Technology in the Service Society: A Twenty-First Century Lever* by the U.S. National Research Council (1994). The Computer Science and

Telecommunications Board (CSTB) of the National Research Council convened a committee to study the impact of Information Technology (IT) on the performance of service activities. IT is an important component in the service sector. As IT became cheaper, more affordable and more and more embedded in various type of devices, the impact of IT investments was more likely to have profound effects on firms, industries and overall national economic performance.

The study was motivated by the fact that government statistics showed, despite massive investments in IT, a slight or inexistent impact on productivity. This was the so-called IT paradox. Different explanations of the paradox were evoked, including mismanagement practices, some offsetting factors, measurement problems, and time lags. To fully understand the economic and social impact of IT on the services sector, the committee used four different levels of analysis and considered both quantitative and qualitative observations.

At the macroeconomic level, the committee examined the constraining effects of looking at services from the traditional perspectives of goods-producing industries. The currently available macroeconomic data could not precisely measure how IT investment alone influenced productivity in services. In fact, the existing data provided by the Bureau of Economic Analysis (BEA) were unable to capture very important features of services sector performance such as quality, flexibility, convenience, variety, reliability and new services created by the use of IT in the services sector. At such, the standard measures of productivity appeared to limit the macroeconomic analysis of service sector productivity.

At the industry level, the use of IT was highly varied within and among the industries. Companies used IT for both operational and strategic purposes. It was often difficult for researchers to isolate the effects of IT use from other factors that influence productivity. But in spite of that difficulty, it was argued that the use of IT had a direct and positive impact on the performance of services industries, even though from a financial perspective the impact might not always have been favourable.

At the firm level, the study found that companies invested in IT to expand their market share, to avoid catastrophic losses, to create greater flexibility, and to improve the quality of products and services offered to customers. These improvements in performance and the overall impacts of IT might not show up in standard financial or macroeconomic data reports. Investments in IT that only shifted market share might indicate little or no measurable benefits at the industry or macroeconomic level whilst they do for an individual firm.

Likewise, the metrics of performance used within enterprises could not be aggregated at a higher level. Indeed, none of the companies could separate the effects of a single input, such as R&D or IT, from other factors that might affect success of a given project. Consequently, they used engineering metrics or results of customer surveys, rather than financial results, to evaluate the potential impacts of an IT investment. In addition to those techniques, managers based, to a large extent, investment in IT on their own intuition or judgments. Therefore, all these practices did not permit aggregation at the industry or macroeconomic levels.

The committee enumerated a number of problems in measuring the impact of IT at the firm level: difficulties in defining units of output that could be consistent over time; capturing or measuring benefits passed through to customers and suppliers; establishing financial measures of the impact of intangible benefits (such as greater reliability and broader selection); estimating the counterfactual of what would have happened without the use of a technology; and measuring changes in productivity when IT transformed the basic nature of the business and the competitive environment.

The committee found that IT did promote many broad restructuring and strategic changes in service industries. IT was used to create new industries and contributed to changes in the traditional relationship between industries. The economies of scale offered by IT in certain cases facilitated merger and acquisitions and led to reductions in the work force as well as the entry of new businesses. The widespread use of IT in services also had profound effects on employment patterns, and changed production processes and firm organization. New jobs were created while others were destroyed. The future jobs were predicted to be more knowledge-based than in the past.

ICT and Productivity: Empirical Results

This section, reviews a number of studies on the impact of ICT on productivity growth. The studies have been broken down into those for the United States, Canada, other OECD countries such as France and the United Kingdom, and studies on a range of countries, called international studies.

The first wave of empirical analyses on that topic (e.g. Franke (1987), Loveman (1988), Strassman (1990), Wolff (1999) and Lee and Gholami (2002)) actually found little evidence of any productivity impact of ICT investment: Alpar and al. (1991) noted that this result may have been affected by the methodology used to assess the impact of IT.

This early conclusion, and the famous quip in 1987 by the Nobel Prize laureate Robert Solow mentioned earlier created the so-called “productivity paradox.” Brynjolfsson (1993) tried to account for this productivity paradox by evoking the presence of measurement errors, time lags, and mismanagement practices. The paradox and the steady computerization of the economy during the 1990s spurred a burst of academic research on the potential linkages between ICT and productivity.

In this research, different levels of analysis and methodologies were used. Researchers worked at three levels: the macroeconomic or total economy level; the industry or sector level; and the firm level. Methodologies employed varied with the purpose of the study. The vast majority used a growth accounting framework based on neoclassical assumptions; an econometric approach; or a case study approach, or some combination of the three.

Studies on the United States

There have been more studies on the effects of ICT on productivity done for the United States than for any other country. This section looks at the US studies done at the aggregate, industry and firm level.

Aggregate level studies

At the macroeconomic level, studies essentially focused on the contribution of ICT to aggregate output and productivity growth. National and cross-country perspectives are commonly used.

Dan Sichel

Dan Sichel (1997) from the Federal Reserve Board quantified the computer revolution in a simple growth accounting framework. He found that computer hardware made a modest contribution to output growth and labour productivity in the 1970-92 period. Output growth during that period averaged 2.8 per cent annually and computer hardware contributed only 0.15 percentage points annually. In the 1980-1992 period, compared to the 1970-1979 period, the contribution from computers almost doubled (from 0.09 to 0.2 percentage points a year), but the income share of computers remained well below that of other types of capital. The contribution of non-computer capital swamped that of computer hardware. This assertion that "…other factors have dragged down growth in a way that has masked the contribution of computing services…" was known as the offsetting factors hypothesis (Sichel, 1997:79).

Sichel also found that by extending the growth-accounting calculations to include software and computer-services labour, one could almost double the contribution of computer services (hardware, software and computer labour services) to output and productivity growth. In fact, the contribution of computing services to output growth between 1987 and 1993 was 0.31 percentage points a year, that is double the contribution of hardware alone. Broadening the scope of IT beyond hardware was this crucial for estimating the true contribution of IT to productivity and output growth.

Sichel concluded that even though computing services, computer hardware and software made up a relatively small share of income (2.4 per cent), together they contributed one-quarter-percentage point a year to growth in labour productivity from 1987 to 1993.

Stephen Oliner and Dan Sichel (2000)

Stephen Oliner and Dan Sichel from the Federal Reserve Board (2000) updated earlier work, including Sichel (1997), on the relationship between productivity and IT. They used the same analytical framework, the neoclassical model of growth accounting, to assess the different inputs contribution to growth. They started by breaking down the contribution from the use of IT into semi-conductors and computer production. They found that, as in earlier work, IT capital, from the 1970s to the early 1990s made only a small contribution to growth. But by the late 1990s, from 1996 to 1999, they noticed a surge in the IT contribution to output growth, from 0.57 percentage points in 1991-1995 to 1.10 percentage points in 1996-1999. Equally, the contribution of computer hardware more than doubled between these two periods, from 0.25 percentage points to 0.60 percentage points.

Oliner and Sichel decomposed labour productivity growth into contributions from capital deepening, labour quality and MFP growth. The results showed that labour productivity growth increased from about 1.5 percent per year in the early 1990s (1991-1995) to 2.6 percent per year at the end of the century (1996-1999). Capital deepening related to IT and MFP growth accounted for almost all of this growth.

In addition to the contribution of the use of IT, they looked into the contribution to growth from the production of computers. Specifically, they focused on MFP changes to identify the different growth parts attributable to efficiency improvements in the computer production. Between 1991-1995 and 1996-1999 periods, they found that the sharp decline in the relative prices of computers and semi-conductors and the rising output shares of these two industries largely explained the acceleration in MFP growth.

In terms of the 1 percentage point acceleration in labour productivity growth from 1991-1995 to 1996-1999, they found that 0.45 percentage points could be accounted for by IT capital deepening and a 0.26 percentage points by MFP growth in computer and computer-related semi-conductor production. Those two factors represented two-thirds of the acceleration. If in their earlier work, IT was found to have made a small contribution to labour productivity growth, in this new study, thanks to more recent data, computer services, or IT, were found to be at the center of the resurgence of labour productivity growth.

Robert Gordon

Robert Gordon from Northwestern University has gained a reputation as a skeptic of the benefits of the so-called 'New Economy.' In 2000, in a well known article, Gordon (2000) decomposed the output growth in the United States in the 1990s to assess the contribution of cyclical effects, trend growth, and structural changes to productivity growth. He discovered that the US productivity revival was limited to the durable manufacturing sector and outside of this sector; there was even a structural deceleration in multifactor productivity growth. He concluded that the US productivity revival of the late 1990s essentially took place in computer hardware, peripherals and telecommunications equipment sectors, with a substantial spillover to the 12 percent of the economy involved in manufacturing durable goods. But the remaining 88 percent of the economy stayed unchanged in terms of productivity, with capital deepening being unproductive in these industries. In other words, he argued that the 'New Economy' effect in the United States was concentrated in a particular segment of the economy and was absent elsewhere.

Gordon posed the question why the Internet, which was quickly accessible and cheaper than old inventions, had such a modest impact on productivity growth. Looking at diminishing returns, he argued that the computer industry, like the airline or electric utility industries, had more rapid diminishing returns than other sectors in the economy. The real revolution in productivity took place at the beginning, and improvements thereafter were marginal. He has since recanted this pessimistic view of the productivity-enhancing effect of computers on productivity given the obvious fact that productivity growth has been extremely robust in the United States with the continuation of the computer revolution.

Kevin Stiroh

Kevin Stiroh (2002) from the Federal Reserve Board of New York estimated the impact of ICT capital intensity (the result of investment in ICT) on average labour productivity growth in the US manufacturing sector. In his neo-classical model, investment in ICT capital has an impact on productivity that is proportional to its input share of income, and does not have any additional impact through spillovers. The rapid growth of ICT investment is the result of rapidly falling relative prices for this type of capital relative to other inputs. Stiroh studied the impact of ICT intensity on labour productivity for 20 US manufacturing industries for the 1973-1999 period.

The model related average labour productivity growth to ICT intensity (the share of ICT capital service to total capital services). The objective of the study was to ascertain whether manufacturing firms with above average ICT intensity saw their labour productivity growth accelerate during the 1993-1999 period. The results were affected by the inclusion or non-inclusion of ICT producing manufacturing industries in the sample. When these industries were included, the acceleration of labour productivity growth was almost one percentage point higher than when they were excluded, either for the 1984-93 and 1993-99 comparison, or for the 1973-93 and 1993-99 comparison. But still, even when ICT- producing industries were excluded, ICT-intensive manufacturing firms experienced an acceleration in labour productivity growth at least one percentage point higher than non-ICT-intensive industries. This suggests that faster ICT capital accumulation, leading to higher ICT intensity, allowed for even faster growth during the 1993-1999 period.

Firm level studies

Atrostic and Nguyen

B.K Atrostic and Nguyen (2005) from the US Bureau of the Census have focused on the link between computer networks and productivity. In 2004, Atrostic and Nguyen presented evidence of a significant positive relationship between the productivity of US manufacturing firms and computer networks. However, it was suggested that the non-inclusion of the computer capital stock could have biased the results.

In 2005, the authors updated and extended their earlier study to include computer capital as a separate input in the production function. Using data for new plants, they found that computer network and computer inputs, even when separately incorporated, had a positive and statistically significant relationship with firm-level labour productivity. The estimated impact for computer networks was 12.4 per cent for new plants in 1997 whereas the contribution of computer intensity to labour productivity was 5.1 percent. Similar results were obtained with a larger sample of new plants between 1992 and 1997. For those plants, the estimated computer network impact was 13.4 percent and the contribution of computer intensity was 4.7 percent.

When they extended the sample to include plants of all ages, they found that computer networks had no significant impact on labour productivity whereas computer investment still had a positive and significant contribution (4.89 percent). Therefore when plants of all ages were considered, computer networks did not appear to be a technology that could shift the production function.

Nevertheless, the fact that computer networks had a strong impact for new plants supports the vintage capital model hypothesis. This model asserts that new plants use the most recent embodied technology, whereas older plants leave the market when their productivity becomes too low relative to the new entrants. Their findings suggest that computer networks should be treated as a new technology, distinct from other computer inputs.

Studies on Canada

Aggregate level studies

Conference Board of Canada

The first study of the effects of IT on productivity growth in Canada was published in 2000 by the Conference Board of Canada (2000). This study assessed the contribution to labour productivity of capital deepening in IT by using a three-factor production function, in which the stock of capital was broken down into IT capital stock and other capital stock. It used a measure of total factor productivity, which represented the technical efficiency with which the different factors could create output. A Cobb-Douglas production function was built with a measure for TFP and the three following factors: labour, capital stock attributable to the IT sector and other capital stock.

From this function, they obtained, for the 1978-1990 period, a 0.03 percentage points per year contribution from the IT capital stock to labour productivity growth of 0.58 per cent. This represented a mere 5 per cent contribution. Over the 1991-1995 period, the average annual labour productivity growth rose 1.01 per cent, with an increase in the contribution of IT of 0.12 percentage points or 12 per cent. Over the period 1996-1999, labour productivity growth on an average annual basis declined to 0.87 per cent. But the contribution from IT increased, reaching 0.34 percentage points, more than one third (39 per cent) of labour productivity growth.

Over the three periods, the authors found a steady decline in the contribution of non-IT capital: 0.39 percentage points per year during 1978-1990, 0.26 points during 1991-1995 and -0.33 points in the 1996-1999 period. The authors interpreted this negative contribution from other capital as the fact that the amount of investments and capital accumulation had not been large enough to keep up with the growth in employment. Furthermore, in this study, the contribution from TFP growth exhibited a strong increase over time: 0.16 points per year between 1978 and 1990, 0.64 points between 1991 and 1995 and 0.87 in the 1996-1999 period.

The Conference Board compared these results with recent studies for the United States. The major difference between Canada and the United States was, according to the authors, the surge in labour productivity in the United States during the late half of the 1990s, nearly 2.6 per cent per year, up from 1.5 per cent in the early 1990s, a development that was believed at the time not to be taking place in Canada. Revisions to estimates of output growth have since shown that Canada did in fact experience a significant pick-up in productivity growth after 1996.

Khan and Santos

In 2002, the Bank of Canada also joined the debate. To avoid monetary policy errors, Khan and Santos (2002) argued that the Bank of Canada should improve its macroeconomic forecasts, including the productivity growth forecast. This led to an examination of the role of ICT in contributing to the acceleration in labour productivity growth. They employed a neoclassical Cobb-Douglas production function for the non-farm business sector. They used as inputs: labour (defined as amount of hours worked), the stock of computer hardware, the stock of computer software, the stock of telecommunications equipment, other types of capital stock and an exogenous term for the MFP growth.

The contribution from the use of ICT to labour productivity was determined by the contribution from these three ICT stocks: hardware, software, and telecommunications equipment. This referred to a capital deepening measure. Over the 1996-2000 period, labour productivity growth was at 1.7 per cent per year, with 0.45 percentage points attributable to ICT use, or more than one quarter (26 per cent). Of this 0.45 percentage points contribution from ICT, 0.29 percentage points came from hardware, 0.11 percentage points from software, and 0.05 percentage points from the telecommunications equipment.

The average contribution of ICT capital deepening increased from 0.33 percentage points per year in 1991-1995 to 0.45 percentage points in 1996-2000. Moreover, a compositional change occurred over the 1990s. The average contribution of hardware increased significantly from 0.17 percentage points in 1991-1995 to 0.29 percentage points in 1996-2000. The contribution of hardware to ICT capital deepening rose from about 51 to 64 percent. Software and telecommunications equipment showed little change. Between the two periods, the software contribution rose from 0.10 percentage points in 1991-1995 to 0.11 percentage points in 1996-2000. The telecommunications equipment was even lower for the second period, 0.05 percentage points in 1996-2000 from 0.06 percentage points in 1991-1995.

Armstrong, Harchaoui et al

Armstrong, Harchaoui et al (2002) from Statistics Canada examined the sources of labour productivity in the Canadian business sector. They used a growth-accounting model to examine the contribution from a broad set of classes, including ICT, to productivity growth. They focused on three main factors: the capital deepening, which included ICT, other machinery and equipment and structures, a labour composition effect and MFP growth rate.

They found that, from 1981 to 1988, of the 1.4 per cent annual rate of labour productivity growth, 0.2 percentage points could be attributed to increases in MFP, 0.6 percentage points to capital deepening (0.4 percentage points from ICT, 0.1 percentage points from other machinery, and 0.1 percentage points from structures) and 0.5 percentage points to changes in labour composition.

From 1988 to 1995, of the 1.2 per cent annual rate of labour productivity, -0.3 percentage points was due to MFP, 0.9 percentage points to capital deepening (in which 0.4 percentage points were from ICT, 0.1 percentage points from other machinery and 0.3 percentage points from structures) and 0.6 percentage points to changes to labour composition. ICT represented, in that period, more than two-fifths of the capital deepening contribution to labour productivity growth.

For the 1995-2000 period, the labour productivity grew at 1.7 per cent per year in the business sector, 0.5 percentage points faster than the previous 1988-1995 period. This acceleration could be explained by a 1.0 percentage points increase of MFP (from -0.3 percentage points in the previous period), 0.4 percentage points to capital deepening (0.4 percentage points for ICT, 0.1 percentage points from other machinery and -0.1 percentage points from structures) and 0.3 percentage points to changes in labour quality. During that period, ICT accounted for the entire capital deepening contribution to labour productivity growth.

According to the authors, the labour productivity growth between 1995 and 2000 can be fully explained by the resurgence of MFP growth. They concluded that the recovery in the MFP growth was the most remarkable feature of the data and they suggested that it was probably due to considerable improvements in technology and increases in the efficiency of production.

Harchaoui et al

The study by Tarek Harchaoui et al (2004) from Statistics Canada attempted to provide additional evidence on the sources of growth for labour productivity performance in both Canadian and US industries. To look at the 1981-2000 period, the authors extended the model used in Armstrong, Harchaoui et al (2002). Harchaoui and Tarkhani (2004a) had already refined and extended the previous model by using an augmented growth accounting model entirely integrated to a sectoral model to trace the various channels through which IT operated.

They found that labour productivity revival in Canada was primarily attributable to IT capital deepening and MFP gains of IT-producing industries. They incorporated service flows from the stock of durables instead of expenditures, and they separated university-educated workers from non-university workers. The production function decomposed labour productivity growth into four sources: capital deepening, which was decomposed into non-IT and IT components, a labour quality improvement term, a term for the compositional shifts and one for MFP growth.

For the period 1981-2000, labour productivity growth increased 1.03 per cent per year. The contribution of capital deepening, labour composition and MFP over the period were 0.47, 0.34 and 0.22 percentage points respectively (the corresponding figures for the United States are 1.04, 0.16 and 0.63 percentage points).

Of the 0.47 percentage points contribution of capital deepening in Canada (1.04 percentage points in US), 0.34 came from IT (0.42 for US) and 0.13 (0.62) from non-IT. In Canada (in the US), the contribution of labour composition could be explained by 0.03 percentage points (-0.02 percentage points in the US) from university-educated workers, 0.19 percentage points (0.06 percentage points in the US) from non-university-educated workers and 0.12 percentage points (ibid for the US) from reallocation of hours.

MFP accounted for 0.22 (0.63 in the US) percentage points of the labour productivity growth and could be decomposed into 0.07 (0.33 in the US) percentage points due to IT industries and 0.13 (0.3 in the US) percentage points to non-IT industries. They found that the sources of productivity revival in 1995-2000 were different in Canada and in the United States. In Canada, MFP accounted for 77 percent of the labour productivity growth compared to 31 per cent in the United States. However, capital deepening in the US accounted for 64 percent of the productivity revival compared to 2.3 per cent for Canada. IT even had a negative contribution, -0.27 percentage points, to capital deepening in Canada in 1995-2000.

The authors investigated the sectoral sources of multifactor productivity growth. They attempted to trace the contribution of IT-producing industries to aggregate MFP growth. Canada's IT-producing industries made a consistent positive, albeit small, contribution to aggregate MFP.

In the early 1980s, the IT-using sector made a 44 per cent contribution to MFP and IT-producing industries a 6 per cent contribution. In the late 1990s, the IT-producing sector made a 12 percent contribution while the IT-using sector had an 89 percent impact. In Canada, MFP growth was driven essentially by the IT-using sector. The pattern was completely different in the United States where in the early 1980s the IT-using sector made an equal 28 percent contribution to MFP growth as the IT-producing industries. In the late 1990s, IT-producing sector made a 54 percent contribution to MFP growth while IT-using sector made one of 22 percent.

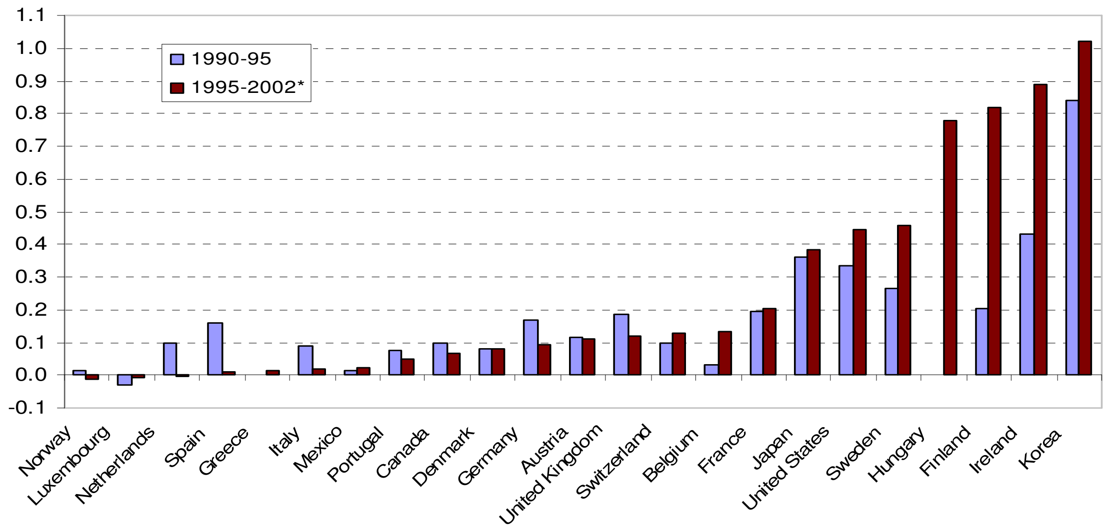
The data revealed that US multifactor productivity growth could be traced to IT-producing industries, which produced computers, semiconductors and other high tech gear. In Canada, the source of MFP revival came from IT-using industries like finance, insurance, real estate and distributive trade industries.

In conclusion, the differences in the sectoral sources of multifactor productivity between Canada and the United States, could stem from differences in the structure of the economies and/or in the sources, concepts and methods in the statistical systems of the two countries.

Dirk Pilat

Dirk Pilat (2005) from the OECD analysed Canada’s productivity performance by comparing it to that of other OECD countries over the 1990-2003 period. He observed that for the 1995-2003 period, Canada actually performed quite well in terms of labour productivity growth. He notes that two factors fostering productivity growth in Canada have been the very high level of human capital and the low barriers to firm creation. The latter facilitates creative destruction by allowing new firms to challenge existing firms and force less productive firms out of the market.

Chart 27: Contribution of ICT manufacturing to aggregate labour productivity growth
(Total economy, value added per person employed, contribution in percentage points)

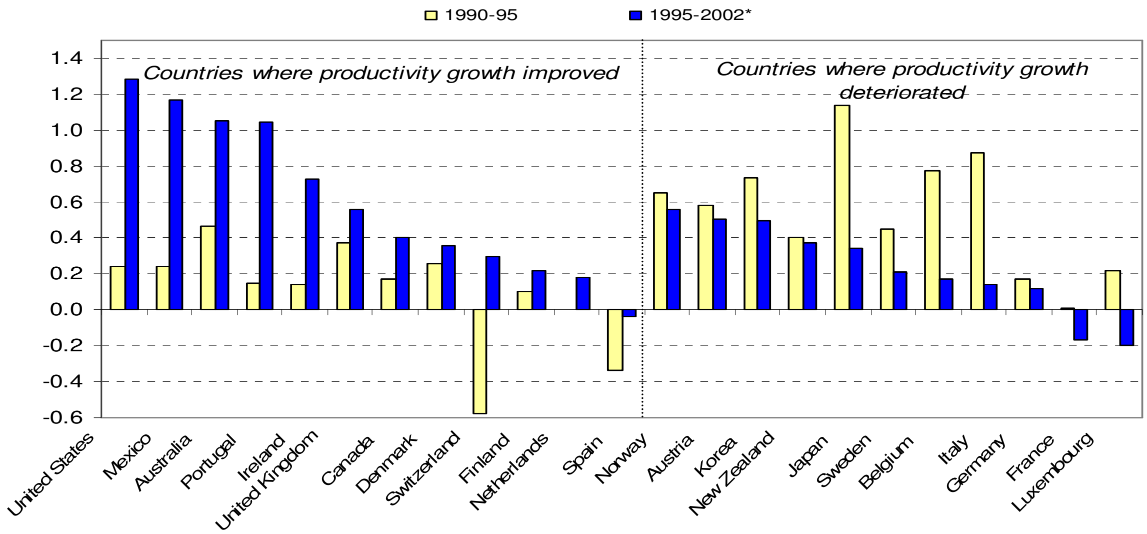


Note: 1991-1995 for Germany; 1992-95 for France and Italy and 1993-1995 for Korea; 1995-99 for Korea and Portugal, 1995-2000 for Ireland, Spain and Switzerland, 1995-2001 for France, Germany, Hungary, Japan, Mexico, the Netherlands, Norway, Sweden, the United Kingdom and the United States.
Source: Pilat, Dirk (2005) "Canada Productivity Performance in International Perspective", International Productivity Monitor, no.10, Spring 2005, p.24-44

Canada also appears to have benefited from innovation driven by ICT use and related organizational changes, especially in the service sector. For the 1990-1995 period, ICT capital contributed 0.34 percentage points to Canada's 1.7 percent annual GDP growth, a 20.0 percent relative contribution (Table 23). ICT hardware contributed the most with a 0.17 percentage point contribution, followed by ICT software and communications equipment with 0.12 and 0.05 percentage points respectively.

During the 1995-2002 period, ICT capital played a larger role in Canada's GDP growth, contributing 0.60 percentage points. However, in relative terms, the contribution represented only 16.5 percent of GDP growth. ICT hardware contribution more than doubled, to about 0.37 percentage points, while software's contribution increased only slightly to 0.14 percentage points, and communications equipment's contribution almost doubled to 0.9.

Chart 28: Contribution of ICT-using services to aggregate labour productivity growth, 1990-95 and 1996-2002
(Total economy, value added per person employed, contributions in percentage points)



Note: ICT-using services are defined as the combination of wholesale and retail trade (ISIC 50-52), financial intermediation (ISIC 65-67) and business services (ISIC 71-74). See Figure 6 for period coverage. Data for Australia are for 1995-2001.
Source: Pilat, Dirk (2005) "Canada Productivity Performance in International Perspective", International Productivity Monitor, no.10, Spring 2005, p.24-44

Pilat found that ICT manufacturing was of little importance for growth in aggregate labour productivity in Canada during the 1990-2002 period (Chart 27). However, he underlined the recent evidence on the importance of ICT use in raising MFP growth. In Canada, ICT-intensive services contributed 0.2 percentage points to the aggregate labour productivity growth for the 1990-1995 period. For the 1995-2002 period, the contribution of ICT-intensive services climbed up to 0.4 percentage points (Chart 28). However, the ICT-intensive services contribution to aggregate labour productivity seems to have been much smaller in Canada than in the United States, even though Canada's ICT performance is still better than in some European countries such as France and Germany. Pilat suggests that a lack of complementary investment might explain the disparity in the effects of ICT investment across countries.

Industry Level Studies

Baldwin et al (2002)

The first paper reviewed in this section presents results on the empirical relationship between ICT and labour productivity at the aggregate level. Baldwin et al. (2002) from Statistics Canada measure the impact of ICT capital deepening on aggregate business sector labour productivity growth over the 1981-1999 period using the standard growth accounting method based on neoclassical assumptions. Their estimates are compared to similar US statistics from the BLS. The authors provide a decomposition of labour productivity growth into three components. The first component is capital deepening (it is further decomposed into ICT capital deepening, other machinery and equipment (M&E) capital deepening, and structures capital deepening). The second component arises from labour quality improvements, and a last component from multifactor productivity (MFP), the residual component of labour productivity growth that cannot be explained by the previous inputs.

Over the 1981-1999 period, the decomposition shows that the contribution to labour productivity growth from ICT capital deepening was equal in Canada and the United States, but that labour productivity growth was half a percentage point higher in the United States. Stronger MFP growth allowed this spread, suggesting that other factors beside capital deepening were present in the United States and not in Canada during the period. But when the 1995-1999 sub-period is considered, the story is quite different. Although the contribution of MFP growth was larger in the United States during this period, the difference was smaller and the gap is explained by larger contributions of ICT and M&E deepening, indicating that US businesses invested more during the period than Canadian firms.

The authors found a relationship between economic performance and advanced technology adoption. The establishments in the top half of the labour productivity growth distribution were more likely to be using at least one advanced technology while the highest productivity growth plants were using a greater number of technologies. Among plants that use all three types of ICT (hardware, software and communications equipments), 54 percent were high-productivity growers and 34 percent slow-productivity growers. Moreover, the highest labour productivity establishments adopted 5.9 advanced technologies compared to 4.7 for the lowest ones.

In comparison with the non-users, ICT users had increased their productivity advantage over time and the largest relative productivity gains occurred in plants that had adopted advanced communications technologies either singly or in combination with other ICT.

In summary, over a decade, a greater amount of market share had been transferred from the declining firms to the growing ones in the Canadian manufacturing sector. Growers increased their productivity relative to the decliners thanks to ICT, with communications technologies playing a special role in the growth. The authors note that although the adoption of ICT is one of the keys to growth, it needs to be accompanied by organizational changes to be successful.

Gu et al

Gu et al (2004) from Statistics Canada examined, through IT-induced organizational innovation and network or spillover effect, the linkage between IT and productivity growth in Canada. They also, with a large sample of 122 industries, examined the hypothesis that human capital and IT were complementary in improving productivity performance in Canadian industries and that opening to international competition leads to benefits in the form of more IT investment.

Using growth accounting techniques, they decomposed aggregate labour productivity growth into contributions from IT capital deepening, non-IT capital deepening, labour quality (or labour composition) and MFP growth. Then, the contribution of labour composition was decomposed into university and non-university workers and compositional shifts between those two groups.

Over 1981-2000, labour productivity growth averaged 1.55 per cent per year. The contribution of capital deepening accounted for 0.54 percentage points of the labour productivity growth (0.39 percentage points from IT and 0.15 percentage points from non-IT), labour quality for 0.37 percentage points (0.02 percentage points for university-workers, 0.19 percentage points for non-university workers and 0.15 percentage points for reallocations hours) and MFP for 0.64 percentage points.

For the 1995-2000 period, all the contribution from capital deepening to labour productivity growth could be accounted for by IT (0.48 percentage points versus -0.08 percentage points for non-IT capital services). In the same period, the authors observed that labour productivity growth was driven by MFP growth, which accounted for 1.06 percentage points out of the 1.91 per cent total growth. The contribution of overall capital deepening decreased in the late 1990s, from 0.64 percentage points in 1988-1995 to 0.40 percentage points in 1995-2000.

MFP growth accelerated in 62 of the 122 industries between 1988-1995 and 1995-2000. These industries included large service industries such as wholesale trade, retail trade, communications and financial services. Moreover, the industries with accelerating MFP growth accounted for the majority of gross output and hours worked, which led the authors to conclude that the post-1995 productivity growth acceleration had been pervasive across Canadian industries.

Before 1995, IT-intensive industries, which were mostly services industries such as wholesale and retail trade, financial and communication services, made little contribution to MFP growth, with almost all MFP growth attributable to non-IT intensive industries.

After 1995, IT-intensive industries made a much larger contribution to MFP growth – 0.71 percentage points compared to only 0.34 percentage points from non-IT intensive industries. Thus, the acceleration in the labour productivity growth was largely due to the increased MFP growth in IT-intensive industries.

Using regression analysis, the authors found a positive coefficient between educated workers and IT intensity, which suggests that the industries that had a larger share of knowledge workers had larger productivity gains from IT. More skill-intensive and more IT-intensive industries had larger gains in productivity growth after 1995. Particularly, they estimated that a 0.1 percentage point increase in the IT capital share and in university workers relative to 1988-1995 was associated with a 0.2 percentage point acceleration in MFP and labour productivity growth in 1995-2000. This represented new evidence that IT and skilled workers were complementary in improving productivity performance.

Firm-level studies

Baldwin and Sabourin

John Baldwin and Sabourin (2002) from Statistics Canada use an econometric model to estimate the relationship between relative labour productivity growth and ICT use at the firm level in the Canadian manufacturing sector over the 1988-1997 period. The estimation relies on data from the Statistics Canada 1998 Survey of Advanced Technologies. The hypothesis was that firms that invest in ICT will eventually be more successful and more productive than their competitors.

To isolate the impact of ICT use on relative labour productivity, the authors control for a number of variables such as foreign ownership, capital intensity, plant size, and R&D activities, variables that are all believed to have a favorable impact on a firm's productivity level. There are three measures of ICT used as regressors, which are aggregates constructed from data for 26 "advanced technologies" from the survey mentioned above. The three aggregates are software, network communications, and hardware technologies. The regression results confirm the authors' hypothesis, as advanced technology use is positively related to relative labour productivity and statistically significant at the 1 percent level. An important result is that there appears to be almost no productivity gains from adopting a single technology (positive or negative coefficient but not statistically significant), either hardware or software. The crucial explanatory variable is the use of network communications technology, which drives the result of a positive impact of ICT use on relative labour productivity.

Turcotte and Rennison

Julie Turcotte and Lori Rennison (2004) from Finance Canada also studied the impact of computer use on labour productivity at the firm level. They used data from Statistics Canada's 1999 Workplace and Employee Survey, which covers non-manufacturing as well as manufacturing industries. The authors used an econometric model to evaluate the impact of technology use on labour productivity levels for a cross section of Canadian firms. They controlled for educational attainment, type of training, firm characteristics, and region.

The technology use variable is the share of workers using computers and it was found to be positively correlated to value added per worker. The impact of a larger share of workers using computers is reduced when industry controls are added to the regression as firms in ICT-intensive industries generally have higher labour productivity levels than those in non-ICT-intensive industries.

The authors also study the complementarity of computer use, training and educational attainment. By combining the three variables, they find that the most important determinant of labour productivity is the share of workers using a computer with no university degree but with training on a personal computer (PC), followed by workers with a university degree as well as training on a PC. It therefore appears that PC training is the key complement to computer use and that educational attainment is not as relevant. The papers shows that the more workers use computers, the more a firm is expected to be productive, and that training workers to better use computers should add even more to the firm's productivity level, even if workers are not university graduates.

Gera and Gu

Surendra Gera from Industry Canada and Wulong Gu from Statistics Canada (2004) also studied the impact of ICT use on firm-level productivity, with a focus on organizational change. Their data source is the same as used by Turcotte and Rennison, that is the 1999 Workplace and Employee Survey from Statistics Canada, but the methodology used is different, namely a probit model which relates the probability of a productivity change to the explanatory variables. Furthermore, they use the survey results to construct five measures of firm performance, one of which being productivity changes.

They also constructed three measures of organizational change based on a variety of variables taken from the survey: production and efficiency practices; human resource management; and product-service quality-related practices.

The regression results indicate that the share of workers using a computer at work is not an important explanatory variable for productivity change in manufacturing while being the most important one in dynamic services and the second most important in distributive services. ICT investment per worker is the relevant technology explanatory variable for manufacturing. Production and efficiency practices, and human resource management, are both important in explaining increases in the probability of productivity change in the three industrial sectors.

The authors re-estimated their model to measure the impact on productivity of combinations of ICT use and organizational change. The complementary hypothesis of ICT and organizational change predicts that firms who combine ICT use and organizational change will be more productive than their less sophisticated rivals. The regression results by sector for each of the three measures of organizational change indicate that this is indeed the case, with the exception of production and efficiency practices in the manufacturing sector, where combining ICT use with this organizational change is not associated with increases in firm productivity.

<u>Other OECD Countries</u>

Cette, Mairesse and Kocoglu

Gilbert Cette, Jacques Mairesse and Yusef Kocoglu (2002) calculated the contribution of ICT capital to both output and labour productivity growth in France's business sector using standard growth accounting for the 1980-2000 period. They found that the contribution of ICT capital to output growth grew in absolute, but not relative, terms between 1990-1995 and 1995-2000, from 0.17 percentage points out of 0.50 per cent per year to 0.36 percentage points out of 2.20 per cent. In both periods, computer equipment made the largest contribution.

The absolute contribution of ICT capital has been fairly stable on average over the 1980-2000 period. ICT capital contributed 0.24 percentage points over the 1980-1990 period and 0.27 percentage points over the 1990-2000 period. The contribution of ICT capital to labour productivity growth followed quite closely the contribution to output growth. The contribution went from 0.20 percentage points over the 1990-1995 period to 0.33 percentage points over the 1995-2000 period. The relative size of the contribution also grew because of a productivity slowdown during the second half of the 1990s. The authors' calculations also show that 0.65 percentage points of labour productivity growth, almost two thirds, were due to MFP growth from ICT producers.

The authors recalculated the contributions according to two other scenarios about ICT price trends and ICT expenditure shares. The first scenario assumes a steadily rising performance of software and communications technologies at the same pace as computers. The result is faster declines in prices for those technologies and therefore stronger growth in real capital. This amounts to attributing to ICT capital a larger part of output growth while reducing the contribution of MFP, since a portion of the "unexplained" growth is in fact due to greater growth in inputs. According to that scenario, the contribution of ICT has almost doubled for the 1995-2000 period. Similar estimates result from the calculation of the ICT contribution using the US share of ICT expenditure on consumption and investment, instead of the share available from French national accounts. These results show that the choice of variables significantly affects their results.

Notaro

Notaro (2004) from London Consulting estimated the contribution of ICT capital to output and labour productivity growth for eleven industrial sectors in the United Kingdom during the 1993-2000 period, using standard growth accounting. He found that the post and communication sector made the largest ICT capital contribution to output growth over the period, with a 3.51 percentage points contribution per year, while the lowest contribution was in mining and quarrying with a -0.03 percentage points contribution. All but two sectors had contributions between -0.03 and 0.44 percentage points, the other exception besides post and communication was the financial intermediation sector, with a 1.59 percentage point contribution. The largest two contributions of ICT capital/labour ratio growth were also in those two sectors.

Using the sectoral contributions, Notaro constructed a decomposition of total economy output and labour productivity, which is consistent with previously published estimates. The decomposition shows that ICT investment contributed 0.57 percentage points per year to economic growth during the 1993-2000 period, which represented 18 percent of the total. In terms of contribution to labour productivity, ICT deepening contributed 0.52 percentage points, representing 26.3 percent of the total.

Criscuolo and Waldron

Criscuolo and Waldron (2003) analyzed the relationship between e-commerce and productivity using data on UK firms available via the Annual Respondents' Database (ARD). They attempted to establish a link between the firms' use of e-commerce and productivity. Atrostic and Nguyen (1999) had already used this methodology to measure the impact of the use of computer networks by U.S. manufacturing firms. The authors treat buying and selling activities separately in order to distinguish the effect of e-commerce as a means of procurement (buying) and its applications (selling). They found that there is an overall positive correlation between the use of computer networks for trading and firm productivity.

E-buying had a positive impact on labour productivity reaching 7.8 percent. However, e-selling caused a 4.5 percent reduction in labour productivity, 1.2 percent loss in the TFP in terms of gross output and 4.8 percent loss in TFP in terms of value-added. The loss of sellers was interpreted as the result of the loss in pricing power resulting from a highly competitive environment. The authors also found that e-buying and e-selling has an equally strong productivity effect in large and small firms. Moreover, both groups of companies showed value-added productivity gains associated with e-procurement, with bigger gains for large firms.

International Studies

Colecchia and Schreyer

Alessandra Colecchia and Paul Schreyer (2002) from the OECD measure the contribution of ICT investment to economic growth for the business sector in selected OECD countries in the 1990s, using standard growth accounting.[8] ICT investment was important in all the countries surveyed in the 1990s, even if some of the countries

[8] This paper improves on Schreyer (2000) on a number of aspects. One difference is that software is included as an ICT asset, which was not the case in the earlier paper. Another difference comes from data sources. ICT investment series are from official national sources instead of private sources, while the coverage period is extended from 1985-1996 to 1980-2000. Two more countries were added to the sample as well.

suffered economic downturns during the period. The ICT share of total investment grew in all countries between 1980 and 2000. As a result, the contribution of ICT to output growth also increased in importance. The ICT capital contribution to output growth in percentage points for the 1990-1995 period was highest in Australia at 0.47 points, while being the lowest in Finland at 0.01 points, which is surprising given its strong high-tech sector. In comparison, during the 1995-1999 period, the largest contribution was in the United States with 0.86 points while the lowest was in Italy with 0.16 points. Canada was roughly half way between the leaders, i.e. Australia and the United States, and the European countries. ICT capital accounted for 0.28 percentage points of output growth during the 1990-1995 period and 0.47 percentage points during the 1995-1999 period.

In relative terms, the ICT capital contribution to output growth as a percentage of total capital contribution was largest in the United States (44 per cent) and lowest in Japan (10.5 per cent) during the 1990-1995 period. For the 1995-1999 period, Finland was the leader with a share of 133 per cent (implying that other types of capital contributed negatively to output growth), with Italy coming last with 19.5 per cent. Canada came second for both periods, with respective shares of 38.8 per cent and 45.2 per cent.

The same decomposition exercise was then repeated using alternative ICT investment series that were harmonized by deflating ICT with consistent price indices across countries. The modification has the most impact for countries whose national deflators differ the most from the harmonized series. The most extreme case is Finland, where the contribution of ICT capital to output growth was almost inexistent when the decomposition is based on national price indexes. When the harmonized price indices are used instead, the contribution for the 1990-1995 period goes from 0.01 to 0.24 and from 0.20 to 0.62 for the 1995-1999 period. But such a difference is an exception rather than the norm.

The ICT capital contribution to output growth in percentage points for the 1990-1995 period, based on the harmonized price indices, was highest in Australia at 0.48 points while the lowest was in France at 0.18 points. As for the 1995-1999 period, the largest contribution was in the United States with 0.86 points while the lowest was again in France with 0.33 points. When the decomposition is based on harmonized prices, Canada's position is much closer to the European countries, mainly because European countries have larger ICT capital contributions than before the adjustment. After harmonization, ICT capital accounts for 0.30 percentage points of output growth during the 1990-1995 period instead of 0.28 and 0.51 percentage points during the 1995-1999 period instead of 0.47.

As for the ICT capital contribution to output growth as a percentage of total capital contribution, the largest share was in Finland with 92.3 percent and the smallest in Japan, with 20.8 percent over the 1990-1995 period. During the 1995-1999 period, the first and last countries were the same with respective shares of 108 percent and 35.5 percent. Canada was again among the leaders with shares of 40.5 percent for 1990-1995 and 47.2 percent for 1995-1999.

OECD

OECD (2003) contains a growth accounting decomposition of output growth that uses recent OECD data and covers the period 1990-2001. Data are from the OECD capital services database. The methodology followed is the same as in Colecchia and Schreyer (2002) and takes into account the differences in national ICT price indices. The percentage point contribution of ICT capital to average annual GDP growth at the total economy level for 1995-2001 was highest in the United States with slightly more than 0.8 percentage points while the lowest was in Portugal, at around 0.3 percentage points. Canada had the second largest contribution with 0.7 percentage points. These results are consistent with those published in earlier studies. For the 1990-1995 period, the United States was still leading OECD countries with an ICT capital contribution of 0.45 percentage points while Italy came last with a contribution slightly higher than 0.1 percentage points. Canada was third, just behind Australia with a contribution slightly above 0.3 percentage points.

Pilat, Lee and van Ark

Dirk Pilat, Frank Lee and Bart van Ark (2002) also studied the impact of ICT on productivity growth during the 1990s, using data from the OECD STAN database. Their work builds on Pilat and Lee (2001). Their calculations are based on growth accounting, and the authors focus on the contributions of specific sectors to aggregate labour productivity growth, instead of the inputs growth contribution. They find that the impact of the ICT sectors, either ICT-producing or ICT-using, varies among OECD countries.

During the 1996-2001 period, the contribution of ICT manufacturing to aggregate labour productivity growth was quite small in absolute terms in most countries compared to OECD leaders. ICT manufacturing in Korea contributed more than a percentage point to aggregate labour productivity while the same sector in Canada contributed less than 0.1 points. That contribution was down from its 1990-1995 level. The contribution of ICT-producing services in Canada was more in-line with what occurred in other OECD countries over the 1996-2001 period. The sector contributed 0.2 percentage points, compared to slightly less than 0.5 points in Germany. The contribution of ICT-using services in Canada was also limited in absolute terms, approximately 0.5 percentage points, compared to more than one percentage points in Mexico and the United States.

In Canada, the ICT-using service sector has been the largest contributor to aggregate labour productivity for both the 1990-1995 and 1996-2000 periods (in terms of its contribution to labour productivity growth). Its contribution represented more than half of total economy labour productivity growth during the first period and roughly a third in the second period. The contribution of ICT producing manufacturing and services sectors grew in the second period accounting for more than a third of labour productivity growth. The United States and Mexico also experienced a strong contribution to labour productivity growth from their ICT using service sector, especially during the second half of the 1990s.

Van Ark, Inklaar and McGuckin

Bart Van ark, Robert Inklaar, and Robert McGuckin(2003a and 2003b) from the Conference Board analyze the contribution of different industries to aggregate labour productivity (measured by value added per worker) in Canada, the United States and the EU, using the shift share method. The authors consider three types of industries: ICT-producing, ICT-using and non-ICT industries. The distinction between ICT-using and non-ICT industries is based on ICT capital intensity, where intensity is measured by the share of ICT capital in total capital services in the United States. To increase the comparability of national productivity trends, the authors used US price indices to deflate output from ICT producing industries. As in Pilat, Lee and van Ark (2002), the motivation is to ascertain if ICT intensive industries contribute disproportionately to aggregate labour productivity growth.

According to the authors' calculations, the contribution to aggregate labour productivity growth of ICT-producing and ICT-using industries increased during the 1995-2000 period compared to the 1990-1995 period in Canada and the United States, while only the ICT-producing contribution increased in the EU. ICT-producing and ICT-using industries already contributed the largest share of growth in the United States during the 1990-1995 period, with almost 88 per cent. But the same became true in Canada and the EU during the 1995-2000 period following the increases.

During the 1995-2000 period, ICT-producing and ICT-using industries contributions accounted for 24 per cent and 47 per cent respectively of aggregate labour productivity growth in Canada, 33 per cent and 29 per cent in the EU, and 30 per cent and 56 per cent in the United States. It therefore appears that ICT-producing and ICT-using industries became the drivers of aggregate labour productivity growth after 1995, especially in North America. The aggregate labour productivity growth decomposition also shows that the labour productivity deceleration experienced in Europe in the latter part of the 1990s was mostly driven by non-ICT industries. The relatively weak labour productivity growth in ICT-using industries could not compensate the falling growth contribution of non-ICT industries.

Studies on ICT, Externalities and Complementary Innovations

One reason why businesses may not invest in ICT as much as is socially optimal is the existence of externalities or spillover effects. Spillovers are generally assumed to be network effects, a consequence of better communications and business relations between firms using ICT. If there are positive spillovers from investment in ICT, the investing firm would not be able to capture all returns on the investment and therefore would not invest as much as is socially optimal. The presence of externalities provides a rationale for state intervention to insure a socially optimal level of investment. It is therefore very important to know if such ICT spillovers exist.

A major problem in measuring spillover effects by using the correlation between ICT capital and MFP is that complementary innovations that result from organizational change associated with ICT investment will also be having a positive impact on MFP. Complementary innovations, in contrast to spillover effects, do not justify government involvement because they do not represent an externality, since a business will capture all the benefits from a complementary innovation (from better work organization for example).

Stiroh

Kevin Stiroh (2000) from the Federal Reserve Board of New York used econometric analysis to verify the 'New Economy' hypothesis of positive spillover effects from ICT investment in the United States . Because of lack of MFP estimates for non-manufacturing sectors, he only studied possible spillover effects in the manufacturing sector, which is a shortcoming since most ICT investment occurs in the services sector. But as Stiroh points out, mismeasurement is less likely to be a problem since output is better measured in manufacturing than in other sectors.

Stiroh uses the neoclassical model to try to capture spillover effects that might arise from ICT investment. His strategy is to estimate the correlation of MFP, as it is measured using growth accounting, with ICT capital. A positive correlation between MFP and ICT capital can be the result of the failure of the neoclassical assumption of equality between the elasticity of output with respect to ICT capital and ICT income share. This would imply that ICT capital contributes more to output than the neoclassical model would predict.

But as the author points out, spillovers are not the only possible cause of correlation between MFP and ICT capital. Even if a correlation were found, measurement errors broadly defined could still explain the result. Inconsistently measuring ICT capital goods because of rapid quality improvements or capturing the effect of complementary innovations instead of spillover effects as previously mentioned, are examples of such measurement errors. The author therefore considers his work as a first and imperfect attempt to evaluate ICT spillovers.

The regression model is a simple one where MFP, as measured by the Bureau of Labor Statistics, is regressed on inputs. If the neoclassical assumptions hold, then the regression coefficients should be equal to zero. The regression results show that indeed, inputs do not have an impact on MFP except for non-ICT capital. The relationship between ICT capital and MFP is negative and appears to be driven by the telecommunications component of ICT capital, especially in the ICT-producing industries. But when ICT- producing industries are controlled for, the relationship is still negative, but is no longer statistically significant. The negative relationship is still surprising and the author suggests that such a relationship could arise in the presence of adjustment costs. The results are therefore not favorable to the hypothesis of spillover effects in US manufacturing industries from ICT investment.

<u>Leung</u>

Danny Leung (2004) from the Bank of Canada evaluated the possible impact of adjustment costs associated with the introduction of new ICT capital, as well as complementary innovations/spillover effects derived from ICT capital, on MFP in the Canadian business sector over the 1961-2001 period. Leung did not attempt to disentangle the two possible sources of an impact of ICT on MFP. He used a modified growth accounting method that takes into account capacity utilization. Based on previous studies, the author assumed constant returns to scale and perfect competition. Adjustment costs and complementary innovations were modeled as functions of the investment-capital ratio (more recent types of capital such as ICT have higher ratios since the amount of this type of capital in use is lower). It is hypothesized that adjustment costs are borne by firms following the investment and have an immediate negative impact on MFP. On the contrary, complementary innovations/spillover effects have a positive impact on MFP but take time to materialize.

As we have seen earlier, ICT capital may require or facilitate a reorganization of the firm, from production to relationships between firms or with customers. Such changes might generate productivity gains over and above what is expected from the use of computers or other types of ICT capital by themselves. But there is significant learning-by-doing involved, which implies a lag between investment and MFP growth. Regression coefficients on ICT investment-capital are therefore expected to be negative for contemporary investment, but positive for lagged investment.

The regression results showed that not all types of investment explain MFP growth. This result is not surprising for traditional capital since, as Leung points out, this type of capital is based on older technology. It is not very likely that such traditional capital would necessitate adjustment costs, since the most effective use of these capital goods would be well known. It is not expected either that traditional capital goods would facilitate organizational changes, require other complementary innovations, or produce spillovers in the form of network effects. But the lack of relationship between ICT investment and MFP is surprising, and suggests that if there are adjustment costs and complementary innovations, they may be canceling each other out. The only statistically significant coefficient was for the third lag of computer hardware investment.

Leung tried other specifications of the relationship between MFP growth and investment growth to check the robustness of his result. He checked for signs of multicolinearity, omitted variables, and measurement problems with the depreciation of capital, but none of the specifications significantly affected the results. Separating his sample in two periods, 1961-1981 and 1982-2001 had an impact on the results. For the earlier period, there appears to be adjustment costs but no complementary innovations later on. For the most recent period, in which there was a generalization of computer use by businesses, there are still signs of adjustment costs outweighing complementary innovations/spillovers immediately after investing in ICT, but the coefficients of lags of investment growth gained in statistical significance. The conclusions derived from the initial specification therefore seem to hold and suggest the presence of complementary innovations/spillover effects in the Canadian business sector for the 1982-2001 period, but only materializing a few years later, which is what is expected.

Pilat, Lee and van Ark

Another way to evaluate the spillover theory, although indirectly, is to compare the MFP contributions of ICT-intensive sectors of the economy to the contribution of less ICT intensive sectors. Dirk Pilat, Frank Lee and Bart van Ark (2002) conducted such a comparison for countries for which sectoral MFP estimates are available from the OECD STAN data base. Unfortunately, estimates for Canada and the United States were not included in that paper. But estimates for Canada are available in OECD (2003).

The data reveal that ICT-producing industries, either in manufacturing or in the services sector, were generally not the most important contributors to MFP growth, especially during the 1990-1995 period. For the 1996-2001 period, they contributed more but still less than half of the total MFP growth.

To compensate for the lack of OECD data on MFP for the United States, the authors refer to results from recent US studies to conclude that there is evidence of strong MFP growth coming from ICT intensive service industries, such as retail trade. The US experience therefore appears to differ from what occurred in European OECD countries, which could mean that spillover effects are not necessarily a consequence of ICT investment.

A similar type of comparison can be applied to a cross section of countries instead of a cross section of economic sectors. Assuming that ICT investment leads to spillovers, an economy that invests more in ICT than other economies should experience higher MFP growth than other economies. OECD (2003) provides a scatter graph of OECD countries for which ICT and MFP data are available (a total of 14 countries), that shows a positive relationship between the change in ICT investment and the change in MFP growth. Countries that increased their investment during the 1990s generally saw their MFP growth rates accelerate more during the same period compared to countries with weaker ICT investment growth. The correlation coefficient for the relationship is fairly high at 0.66 and is statistically significant.

Policy Options

The 2001 OECD volume N*ew Economy: Beyond the Hype* explores the impact of structural shifts in the economy on public policy arising from greater ICT use, especially in terms of fostering productivity growth. The thesis of the study is that focusing solely on policies that provide incentives for greater ICT investment is not sufficient to fully take advantage of the productivity growth potential of ICT. Rather, the authors believe that other determinants of productivity growth should still be taken into account, especially those that interact with ICT to allow for more innovations, either in terms of new products and processes or in terms of firm organization and behavior. This section reviews the policy recommendations contained in the volume, although some of them might not be particularly relevant to the Canadian economy since OECD economies, are still heterogeneous.[9]

The intensity of competition in an economy is a determinant of investment in ICT. A more competitive economy not only puts downward pressure on ICT prices but also forces businesses to invest in new technologies that might provide them with an edge over their competitors. The OECD data shows that Canada already has relatively low ICT costs compared to other OECD countries. An obvious policy to enhance competitiveness is more openness and integration in the globalized economy.

More competition in the telecommunication industry is also emphasized in the OECD report. Lower internet costs allow people to spend more time online and therefore should help the business-to-consumer relationship, as well as facilitate the exchange of large quantities of information between firms. Having more entrants in the telecommunications industry could help achieve this objective.

Canada also has a well educated labour force, which is an advantage, not only because educational attainment is generally related to labour productivity growth, but also because ICT use requires so-called knowledge workers. The complementarity of ICT and technical knowledge therefore requires policy makers to act to ensure a steady supply of workers able to fill technical jobs. The best way to achieve this is for firms themselves to train their employees according to job specifications. But the OECD points out there are very few incentives for firms to behave this way. Since employees are not definitively attached to an employer, they may quit after being trained while employers lose their investment in human capital.

The report proposes to modify the tax treatment of employee training to resemble what is done for physical capital or R&D, that is to give allowances for depreciating human capital. An alternative way would be to provide incentives for workers themselves to obtain more qualifications by creating a more thorough certification system for workers. It is believed that if workers have a way to certify their skill level which would be recognized by potential employers, they will be more willing to invest in learning new skills. An example could be a certification program for ICT literacy.

The report suggests modifications to higher education for the adaptation to the new economy. It notes that some OECD countries have introduced what is called 'short cycle programs' whose purpose is to provide applied courses based on the needs of the labour market. This type of program would require the input of the corporate sector. School-to-work transitions could possibly be improved through apprenticeships, which already exist in the form of coop programs, but are not generalized to the entire college

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[9] The reader should note that the OECD publication *ICT and Economic Growth: Evidence from OECD Countries, Industries and Firms* (2003) is a follow up on *The New Economy: Beyond the Hype*. The fourth chapter of this publication contains policy implications, which are essentially the same as the ones from OECD (2001) reviewed next.

population. And since a rapidly changing technological environment requires people to upgrade their skills, the authors of the OECD study suggest making college training more flexible for adult enrollment, which usually require part-time studying because of work constraints.

The OECD report devotes a whole section to policies that foster firm creation, since it is believed that new firms are usually more innovative and more willing to invest in riskier activities and in high-tech capital, especially in the ICT sector, although they usually lack borrowing capabilities. Helping firm creation would help increase ICT investment and because of the innovative activities of new firms, it might lead to new processes, products, and perhaps organizational changes that would improve labour productivity growth. Based on OECD data, Canada was already among the leaders in the 1990s in terms of start-ups activity (percent of adults engaged in firm creation) and new firm activity (percentage of adults owning a new firms, i.e. less than 42 months old).

The ICT industry in the United States has benefited from funding in the form of venture capital. The authors suggest that the Canadian tax on capital gains may act as a disincentive for investors to put funds into risky economic activities, such as high tech start-ups. Other disincentives may be restrictions on the degree of risk institutional investors such as pension funds or insurance companies are legally allowed to take. The report recommends that government try to balance the benefits of increased venture capital and the cost of additional risk taking.

The OECD also produces indicators of barriers to entrepreneurship, which again work as a constraint on firm creation and ultimately on ICT investment and possible productivity improvements. These indicators are: administrative burdens on start-ups, regulatory and administrative opacity, and barriers to competition. The administrative burdens on start-ups level in Canada is approximately half the OECD average. Canada placed second as the country with the least barriers to entrepreneurship. The length of time over which creditors can claim assets from a bankrupt individual is also the shortest in Canada among the OECD countries, which makes it easier for a bankrupt individual to start up a company later on. Canadian policy makers should probably focus elsewhere than on administrative burdens to foster investment in ICT.

Summary

This section began with a summary of Brynjolfsson and Hitt (2000), which highlighted how ICT could generate productivity improvements. The main idea was that the computer and communications technology are flexible inputs that allow firms to fundamentally reorganize the production and distribution of goods and services in order to improve efficiency. But it was also stressed that these reorganizations must be accompanied by investments in complementary intangible assets, which are essentially the results of firms learning how to best use the flexible inputs. The following section presented empirical results on the impact of ICT on productivity and economic growth. ICT contributed positively to labour productivity and economic growth and was in fact the most important contributor in Canada. ICT intensive sectors also appeared to be the drivers of aggregate labour productivity growth.

Based on the results from the third section, the search for ICT spillovers by indirect estimation was inconclusive. Most studies provided weak evidence of such positive complementary innovations/spillover effects occurring at the time of investment. However, these could possibly take time to materialize and appear in the data, which is what the Leung study suggested. In any case, the results should not be taken as a justification for government involvement because of the possible entanglement of two distinct effects (spillovers and complementary innovations). Finally, the last section discussed policy suggestions from the OECD to make the economic environment more favorable to ICT investment. Encouraging skill acquisition by workers and modifying the tax treatment of human capital and venture capital were probably the most relevant options reviewed.

Conclusion

This report has examined ICT investment and capital stock trends in Canada, discussed the relationship between ICT and productivity and provided a review of the literature on the relationship between ICT and productivity in Canada, the United States and other OECD countries.

The key conclusion of the report is that ICT has been the driving force behind the acceleration of productivity growth in Canada and the United States since 1996. However, the potential of ICT has not been fully exploited and we will continue to see significant ICT contributions to productivity growth in coming years. The role for government is to develop appropriate policy frameworks so that the productivity-enhancing effects of ICT can be fully realized.

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Table 1: Current Dollar ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment					Capital Stock		
	ICT Investment, millions of current dollars	Total Non-residential Investment, millions of current dollars	Proportion of ICT Investment in Total Non-residential Investment, per cent	GDP, millions of current dollars	Proportion of ICT investment in GDP, per cent	ICT Geometric End-year Net Stock, millions of current dollars	Total Geometric End-year Non-residential Net Stock, millions of current dollars	Proportion of ICT Stock in Total Stock, per cent
	A	B	C=A/B*100	D	E=A/D*100	F	G	H=F/G*100
1980	4,228	55,461	7.62	314,390	1.34	15,958	595,689	2.68
1981	5,699	68,314	8.34	360,471	1.58	17,604	685,669	2.57
1982	5,796	66,224	8.75	379,859	1.53	21,544	766,207	2.81
1983	6,203	62,821	9.87	411,386	1.51	23,795	798,276	2.98
1984	7,147	66,126	10.81	449,582	1.59	26,155	841,147	3.11
1985	7,614	73,281	10.39	485,714	1.57	28,223	893,950	3.16
1986	8,594	75,792	11.34	512,541	1.68	30,260	941,380	3.21
1987	10,760	82,751	13.00	558,949	1.92	33,525	991,870	3.38
1988	11,540	94,958	12.15	613,094	1.88	36,243	1,062,100	3.41
1989	13,006	103,157	12.61	657,728	1.98	39,014	1,144,805	3.41
1990	13,641	104,156	13.10	679,921	2.01	42,266	1,215,561	3.48
1991	13,507	98,770	13.67	685,367	1.97	44,073	1,228,570	3.59
1992	14,823	92,157	16.08	700,480	2.12	44,886	1,239,295	3.62
1993	15,686	92,458	16.97	727,184	2.16	48,681	1,278,618	3.81
1994	17,190	103,709	16.58	770,873	2.23	51,395	1,342,811	3.83
1995	17,941	108,091	16.60	810,426	2.21	52,378	1,394,707	3.76
1996	19,255	111,687	17.24	836,864	2.30	54,076	1,450,346	3.73
1997	22,568	131,074	17.22	882,733	2.56	60,558	1,523,612	3.97
1998	25,656	139,104	18.44	914,973	2.80	66,826	1,597,219	4.18
1999	29,116	149,113	19.53	982,441	2.96	72,266	1,667,090	4.33
2000	31,866	157,432	20.24	1,076,577	2.96	80,373	1,763,546	4.56
2001	32,086	161,902	19.82	1,108,048	2.90	87,869	1,827,123	4.81
2002	29,908	159,570	18.74	1,152,905	2.59	91,122	1,892,799	4.81
2003	29,970	164,790	18.19	1,213,408	2.47	87,635	1,938,046	4.52
2004	32,188	175,088	18.38	1,290,788	2.49	90,113	2,051,592	4.39
2005	33,208	189,276	17.54	1,371,425	2.42	92,179	2,138,285	4.31
	Average Annual Growth Rate, %							
80-05	8.59	5.03	3.39	6.07	2.38	7.27	5.25	1.92
80-87	14.27	5.88	7.92	8.57	5.26	11.19	7.56	3.38
87-05	6.46	4.70	1.68	5.11	1.28	5.78	4.36	1.36
87-95	6.60	3.40	3.10	4.75	1.76	5.74	4.35	1.33
95-05	6.35	5.76	0.56	5.40	0.90	5.82	4.37	1.39
95-00	12.17	7.81	4.05	5.84	5.98	8.94	4.80	3.95
00-05	0.83	3.75	-2.82	4.96	-3.94	2.78	3.93	-1.11

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Table 2: Current Dollar Software ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment				Capital Stock		
	Software ICT Investment*, millions of current dollars	Proportion of Software ICT Investment in Total ICT Investment, per cent	Proportion of Software ICT Investment in Total Non-residential Investment, per cent	Proportion of Software ICT investment in GDP, per cent	Software ICT Geometric End-year Net Stock*, millions of current dollars	Proportion of Software ICT Geometric End-year stock in Total ICT Geometric End-year Net Stock, per cent	Proportion of Software ICT Stock in Total Stock, per cent
	A	B	C	D	E	F	G
1980	868	20.5	1.56	0.28	1,234	7.7	0.21
1981	1,072	18.8	1.57	0.30	1,467	8.3	0.21
1982	1,339	23.1	2.02	0.35	1,953	9.1	0.25
1983	1,578	25.4	2.51	0.38	2,497	10.5	0.31
1984	1,929	27.0	2.92	0.43	3,044	11.6	0.36
1985	2,243	29.5	3.06	0.46	3,696	13.1	0.41
1986	2,742	31.9	3.62	0.54	4,324	14.3	0.46
1987	3,191	29.7	3.86	0.57	5,181	15.5	0.52
1988	3,927	34.0	4.14	0.64	6,191	17.1	0.58
1989	4,456	34.3	4.32	0.68	7,220	18.5	0.63
1990	5,067	37.1	4.87	0.75	8,329	19.7	0.69
1991	5,315	39.3	5.38	0.78	9,528	21.6	0.78
1992	5,486	37.0	5.95	0.78	9,471	21.1	0.76
1993	6,619	42.2	7.16	0.91	10,855	22.3	0.85
1994	7,577	44.1	7.31	0.98	12,420	24.2	0.92
1995	7,602	42.4	7.03	0.94	13,155	25.1	0.94
1996	8,485	44.1	7.60	1.01	14,110	26.1	0.97
1997	9,566	42.4	7.30	1.08	15,806	26.1	1.04
1998	10,784	42.0	7.75	1.18	17,576	26.3	1.10
1999	11,852	40.7	7.95	1.21	19,239	26.6	1.15
2000	12,228	38.4	7.77	1.14	21,108	26.3	1.20
2001	13,495	42.1	8.34	1.22	22,910	26.1	1.25
2002	12,930	43.2	8.10	1.12	22,902	25.1	1.21
2003	13,502	45.1	8.19	1.11	22,727	25.9	1.17
2004	14,304	44.4	8.17	1.11	23,765	26.4	1.16
2005	14,647	44.1	7.74	1.07	24,598	26.7	1.15
80-05	11.97	3.11	6.60	5.56	12.72	5.08	7.10
80-87	20.45	5.40	13.75	10.94	22.75	10.40	14.13
87-05	8.83	2.23	3.94	3.54	9.04	3.08	4.48
87-95	11.46	4.56	7.80	6.40	12.35	6.26	7.67
95-05	6.78	0.40	0.96	1.31	6.46	0.61	2.00
95-00	9.97	-1.96	2.01	3.90	9.92	0.90	4.88
00-05	3.68	2.82	-0.07	-1.22	3.11	0.32	-0.79

Source: CSLS ICT database based on Statistics Canada's unpublished data.
*Software investment and capital stock for 1980 is calculated as a residual.

Table 3: Current Dollar Computer ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment				Capital Stock		
	Computer ICT Investment, millions of current dollars	Proportion of Computer ICT Investment in Total ICT Investment, per cent	Proportion of Computer ICT Investment in Total Non-residential Investment, per cent	Proportion of Computer ICT investment in GDP, per cent	Computer ICT Geometric End-year Net Stock, millions of current dollars	Proportion of Computer ICT Geometric End-year stock in Total ICT Geometric End-year Net Stock, per cent	Proportion of ICT Computer Stock in Total Stock, per cent
	A	B	C	D	E	F	G
1980	1,576	37.3	2.84	0.50	2,297	14.4	0.39
1981	2,522	44.3	3.69	0.70	3,123	17.7	0.46
1982	2,338	40.3	3.53	0.62	4,106	19.1	0.54
1983	2,702	43.6	4.30	0.66	4,364	18.3	0.55
1984	3,016	42.2	4.56	0.67	5,128	19.6	0.61
1985	3,164	41.6	4.32	0.65	5,682	20.1	0.64
1986	3,372	39.2	4.45	0.66	6,134	20.3	0.65
1987	4,499	41.8	5.44	0.80	7,389	22.0	0.74
1988	4,012	34.8	4.22	0.65	8,084	22.3	0.76
1989	4,518	34.7	4.38	0.69	8,602	22.0	0.75
1990	4,205	30.8	4.04	0.62	9,026	21.4	0.74
1991	3,983	29.5	4.03	0.58	8,418	19.1	0.69
1992	4,747	32.0	5.15	0.68	8,931	19.9	0.72
1993	4,702	30.0	5.09	0.65	10,024	20.6	0.78
1994	5,512	32.1	5.32	0.72	11,152	21.7	0.83
1995	6,227	34.7	5.76	0.77	12,104	23.1	0.87
1996	6,444	33.5	5.77	0.77	11,739	21.7	0.81
1997	7,211	32.0	5.50	0.82	13,390	22.1	0.88
1998	9,434	36.8	6.78	1.03	15,704	23.5	0.98
1999	10,458	35.9	7.01	1.06	17,287	23.9	1.04
2000	11,392	35.7	7.24	1.06	19,777	24.6	1.12
2001	10,336	32.2	6.38	0.93	21,278	24.2	1.16
2002	9,628	32.2	6.03	0.84	21,441	23.5	1.13
2003	9,546	31.9	5.79	0.79	20,485	23.4	1.06
2004	9,564	29.7	5.46	0.74	20,337	22.6	0.99
2005	10,482	31.6	5.54	0.76	20,331	22.1	0.95
80-05	7.87	-0.66	2.70	1.70	9.11	1.72	3.68
80-87	16.17	1.66	9.71	7.00	18.17	6.28	9.87
87-05	4.81	-1.55	0.10	-0.29	5.78	0.00	1.36
87-95	4.15	-2.30	0.73	-0.58	6.36	0.59	1.93
95-05	5.34	-0.95	-0.39	-0.05	5.32	-0.47	0.92
95-00	12.84	0.59	4.66	6.61	10.32	1.26	5.26
00-05	-1.65	-2.46	-5.21	-6.30	0.55	-2.16	-3.25

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Table 4: Current Dollar Communications ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment				Capital Stock		
	Communication ICT Investment, millions of current dollars	Proportion of Communication ICT Investment in Total ICT Investment, per cent	Proportion of Communication ICT Investment in Total Non-residential Investment, per cent	Proportion of Communication ICT investment in GDP, per cent	Communication ICT Geometric End-year Net Stock, millions of current dollars	Proportion of Communication ICT Geometric End-year stock in Total ICT Geometric End-year Net Stock, per cent	Proportion of Cumminication ICT Capital Stock in Total Stock, per cent
	A	B	C	D	E	F	G
1980	1,785	42.2	3.22	0.57	12,428	77.9	2.09
1981	2,105	36.9	3.08	0.58	13,014	73.9	1.90
1982	2,119	36.6	3.20	0.56	15,484	71.9	2.02
1983	1,923	31.0	3.06	0.47	16,933	71.2	2.12
1984	2,202	30.8	3.33	0.49	17,983	68.8	2.14
1985	2,206	29.0	3.01	0.45	18,846	66.8	2.11
1986	2,480	28.9	3.27	0.48	19,802	65.4	2.10
1987	3,069	28.5	3.71	0.55	20,955	62.5	2.11
1988	3,601	31.2	3.79	0.59	21,968	60.6	2.07
1989	4,032	31.0	3.91	0.61	23,192	59.4	2.03
1990	4,369	32.0	4.19	0.64	24,910	58.9	2.05
1991	4,209	31.2	4.26	0.61	26,127	59.3	2.13
1992	4,589	31.0	4.98	0.66	26,485	59.0	2.14
1993	4,366	27.8	4.72	0.60	27,803	57.1	2.17
1994	4,101	23.9	3.95	0.53	27,823	54.1	2.07
1995	4,112	22.9	3.80	0.51	27,119	51.8	1.94
1996	4,325	22.5	3.87	0.52	28,227	52.2	1.95
1997	5,791	25.7	4.42	0.66	31,362	51.8	2.06
1998	5,438	21.2	3.91	0.59	33,546	50.2	2.10
1999	6,806	23.4	4.56	0.69	35,740	49.5	2.14
2000	8,246	25.9	5.24	0.77	39,488	49.1	2.24
2001	8,255	25.7	5.10	0.75	43,681	49.7	2.39
2002	7,350	24.6	4.61	0.64	46,779	51.3	2.47
2003	6,922	23.1	4.20	0.57	44,423	50.7	2.29
2004	8,320	25.8	4.75	0.64	46,011	51.1	2.24
2005	8,079	24.3	4.27	0.59	47,251	51.3	2.21
			1.05	0.02			0.12
80-05	6.23	-2.18	1.14	0.15	5.49	-1.66	0.23
80-87	8.05	-5.44	2.05	-0.47	7.75	-3.09	0.18
87-05	5.52	-0.88	0.78	0.39	4.62	-1.10	0.25
87-95	3.72	-2.70	0.32	-0.98	3.28	-2.33	-1.03
95-05	6.99	0.60	1.16	1.50	5.71	-0.10	1.29
95-00	14.93	2.46	6.60	8.59	7.80	-1.04	2.86
00-05	-0.41	-1.23	-4.01	-5.12	3.65	0.85	-0.26

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Table 5: Distribution of Current Dollar ICT Investment and Capital Stock in Canada by Industry, per cent, 2005

	Total Non-Residential		Total ICT		Computer ICT		Communication ICT		Software ICT	
	Investment	Capital Stock	Investment	Capital Stock	Investment	Capital Stock	Investment	Capital Stock	Investment	Capital Stock
Business Sector	81.7	73.5	85.1	86.5	82.3	81.0	93.2	91.3	82.6	81.9
Goods Sector										
Agriculture Forestry Fishing and Hunting	2.5	2.9	0.5	0.3	0.6	0.7	0.4	0.2	0.4	0.4
Mining and Oil and Gas Extraction	19.8	14.8	1.2	0.7	1.5	1.3	1.0	0.5	1.1	0.8
Utilities	8.1	13.2	4.9	4.4	n.a	n.a	n.a	n.a	n.a	n.a
Construction	2.3	1.1	0.8	0.8	1.9	2.8	n.a	n.a	0.4	0.5
Manufacturing	11.5	10.4	9.3	5.3	9.8	8.2	2.2	1.2	12.7	11.0
Service Sector										
Wholesale Trade	2.4	1.2	6.0	3.6	6.1	5.5	1.0	0.8	8.6	7.7
Retail Trade	3.6	2.6	4.4	2.6	5.6	4.7	0.7	0.6	5.5	4.7
Transportation and Warehousing	6.4	8.4	4.7	4.0	4.5	5.0	2.8	2.4	5.9	6.3
Information and Cultural Industries	4.9	4.5	19.3	38.7	4.4	4.1	64.1	70.3	5.2	6.7
Finance and Insurance	8.6	3.2	13.7	10.7	10.8	13.4	3.8	3.6	21.1	22.2
Real Estate Rental and Leasing	6.5	7.6	6.7	4.7	10.1	9.3	2.1	1.8	6.8	6.5
Professional Scientific and Technical Services	1.7	0.6	7.9	6.2	12.3	11.9	9.6	5.2	3.9	3.4
Management of Companies and Enterprises	0.1	0.0	0.3	0.2	0.4	0.4	0.0	0.0	0.3	0.3
Administrative and Support	0.6	0.2	2.0	1.4	3.8	3.8	n.a	0.4	1.0	1.3
Educational Services	3.1	4.9	3.0	2.3	5.5	6.1	0.3	0.5	2.8	2.7
Health Care and Social Assistance	3.2	3.2	2.1	1.7	n.a	n.a	n.a	n.a	n.a	n.a
Arts Entertainment and Recreation	0.9	0.7	1.4	0.8	2.8	1.9	0.4	0.4	0.9	0.6
Accommodation and Food Services	1.1	1.3	0.8	0.3	n.a	n.a	n.a	n.a	n.a	n.a
Other Services(except Public. Admin.)	0.9	0.8	1.5	1.6	1.9	2.5	n.a	0.5	2.3	2.9
Public Administration	12.0	18.4	9.7	9.4	9.1	9.4	5.8	7.7	12.4	12.9
Total Economy	100.0	100.0	100	100	100	100	100	100	100	100

Source: Source: CSLS ICT database based on Statistics Canada's unpublished data: Table 1a-4a and 9a-w to 12a-w.

Table 6: Chained Dollar (1997 base year) ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment					Capital Stock		
	ICT Investment, millions of chained 1997 dollars	Total Non-residential Investment, millions of chained 1997 dollars	Proportion of ICT Investment in Total Non-residential Investment, per cent	GDP, millions of constant 1997 dollars	Proportion of ICT investment in GDP, per cent	ICT Geometric End-year Net Stock, millions of chained 1997 dollars	Total Geometric End-year Non-residential Net Stock, millions of chained 1997 dollars	Proportion of ICT Stock in Total Stock, per cent
	A	B	C=A/B*100	D	E=A/D*100	F	G	H=F/G*100
1980	1,411	66,448	2.12	576,398	0.24	7,773	928,157	0.84
1981	2,048	78,575	2.61	594,082	0.34	9,403	981,735	0.96
1982	2,015	71,161	2.83	576,744	0.35	10,516	1,020,262	1.03
1983	2,459	67,175	3.66	592,684	0.41	11,738	1,051,160	1.12
1984	2,997	69,869	4.29	626,378	0.48	13,108	1,081,440	1.21
1985	3,435	75,706	4.54	660,318	0.52	14,430	1,114,723	1.29
1986	4,202	77,233	5.44	677,802	0.62	16,014	1,145,455	1.40
1987	5,724	84,001	6.81	705,701	0.81	18,461	1,180,193	1.56
1988	6,463	95,658	6.76	740,592	0.87	20,849	1,223,011	1.70
1989	8,019	101,861	7.87	759,821	1.06	23,943	1,267,856	1.89
1990	8,836	101,340	8.72	762,381	1.16	26,881	1,307,457	2.06
1991	9,834	98,015	10.03	747,857	1.31	29,657	1,340,463	2.21
1992	11,545	94,536	12.21	754,835	1.53	33,482	1,366,765	2.45
1993	12,425	93,783	13.25	772,498	1.61	37,036	1,389,892	2.66
1994	14,174	103,411	13.71	810,016	1.75	41,319	1,419,778	2.91
1995	15,868	107,598	14.75	832,138	1.91	46,191	1,449,862	3.19
1996	18,456	112,710	16.37	845,157	2.18	52,431	1,480,517	3.54
1997	22,568	131,074	17.22	882,734	2.56	60,558	1,523,612	3.97
1998	27,365	138,346	19.78	919,000	2.98	70,179	1,566,995	4.48
1999	33,882	150,377	22.53	969,242	3.50	82,419	1,613,813	5.11
2000	38,835	157,707	24.62	1,020,258	3.81	95,848	1,659,594	5.78
2001	40,162	161,101	24.93	1,036,048	3.88	106,864	1,701,928	6.28
2002	39,030	158,238	24.67	1,066,843	3.66	113,571	1,736,676	6.54
2003	43,416	169,918	25.55	1,091,014	3.98	122,554	1,777,272	6.90
2004	50,005	181,005	27.63	1,131,617	4.42	134,465	1,822,098	7.38
2005	56,084	197,534	28.39	1,169,144	4.80	146,809	1,873,060	7.84
	Average Annual Growth Rate, %							
80-05	15.87	4.45	10.93	2.87	12.64	12.47	2.85	9.36
80-87	22.15	3.41	18.12	2.93	18.66	13.15	3.49	9.34
87-05	13.52	4.87	8.25	2.84	10.38	12.21	2.60	9.37
87-95	13.59	3.14	10.13	2.08	11.28	12.15	2.61	9.30
95-05	13.46	6.26	6.77	3.46	9.66	12.26	2.59	9.42
95-00	19.60	7.95	10.80	4.16	14.83	15.72	2.74	12.63
00-05	7.63	4.61	2.89	2.76	4.73	8.90	2.45	6.30

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Table 7: Chained Dollar (1997 base year) Software ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment				Capital Stock		
	Software ICT Investment, millions of chained 1997 dollars	Proportion of Software ICT Investment in Total ICT Investment, per cent	Proportion of Software ICT Investment in Total Non-residential Investment, per cent	Proportion of Software ICT investment in GDP, per cent	Software ICT Geometric End-year Net Stock*, millions of chained 1997 dollars	Proportion of Software ICT Capital Stock in Total ICT Capital Stock, per cent	Proportion of Software ICT Stock in Total Stock, per cent
	A	B	C	D	E	F	G
1980	n.a	n.a	n.a	n.a	n.a	n.a	n.a
1981	767	37.4	0.98	0.13	975	10.4	0.10
1982	914	45.4	1.28	0.16	1,246	11.9	0.12
1983	1,082	44.0	1.61	0.18	1,540	13.1	0.15
1984	1,329	44.4	1.90	0.21	1,921	14.7	0.18
1985	1,536	44.7	2.03	0.23	2,303	16.0	0.21
1986	1,960	46.7	2.54	0.29	2,848	17.8	0.25
1987	2,315	40.5	2.76	0.33	3,457	18.7	0.29
1988	2,937	45.4	3.07	0.40	4,274	20.5	0.35
1989	3,522	43.9	3.46	0.46	5,198	21.7	0.41
1990	4,169	47.2	4.11	0.55	6,204	23.1	0.47
1991	4,479	45.5	4.57	0.60	6,990	23.6	0.52
1992	5,003	43.3	5.29	0.66	7,947	23.7	0.58
1993	6,108	49.2	6.51	0.79	9,315	25.2	0.67
1994	7,121	50.2	6.89	0.88	10,926	26.4	0.77
1995	7,349	46.3	6.83	0.88	12,166	26.3	0.84
1996	8,314	45.0	7.38	0.98	13,833	26.4	0.93
1997	9,566	42.4	7.30	1.08	15,806	26.1	1.04
1998	11,047	40.4	7.98	1.20	18,031	25.7	1.15
1999	12,225	36.1	8.13	1.26	20,256	24.6	1.26
2000	12,299	31.7	7.80	1.21	21,712	22.7	1.31
2001	13,407	33.4	8.32	1.29	23,095	21.6	1.36
2002	13,095	33.6	8.28	1.23	23,239	20.5	1.34
2003	14,583	33.6	8.58	1.34	24,464	20.0	1.38
2004	16,021	32.0	8.85	1.42	26,359	19.6	1.45
2005	17,014	30.3	8.61	1.46	27,755	18.9	1.48
							1.38
80-05	13.79*	-0.87*	9.50*	10.63*	14.97*	2.53*	11.92*
80-87	20.23**	1.30*	18.90**	16.83**	23.48**	1.30**	19.75**
87-05	11.72	-1.59	6.53	8.63	12.27	0.05	9.42
87-95	15.53	1.71	12.01	13.18	17.03	4.36	14.06
95-05	8.76	-4.14	2.35	5.12	8.60	-3.26	5.85
95-00	10.85	-7.32	2.69	6.42	12.28	-2.97	9.29
00-05	6.71	-0.86	2.01	3.84	5.03	-3.55	2.52

Source: CSLS ICT database based on Statistics Canada's unpublished data.
*Growth rate is for 81-05 instead of 80-05
**Growth rate is for 81-87 instead of 80-87

Table 8: Chained Dollar (1997 base year) Computer ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment				Capital Stock		
	Computer ICT Investment, millions of chained 1997 dollars	Proportion of Computer ICT Investment in Total ICT Investment, per cent	Proportion of Computer ICT Investment in Total Non-residential Investment, per cent	Proportion of Computer ICT investment in GDP, per cent	Computer ICT Geometric End-year Net Stock, millions of chained 1997 dollars	Proportion of Computer ICT Capital Stock in Total ICT Capital Stock, per cent	Proportion of ICT Computer Stock in Total Stock, per cent
	A	B	C	D	E	F	G
1980	75	5.3	0.11	0.01	85	1.1	0.01
1981	180	8.8	0.23	0.03	163	1.7	0.02
1982	166	8.2	0.23	0.03	223	2.1	0.02
1983	271	11.0	0.40	0.05	335	2.9	0.03
1984	356	11.9	0.51	0.06	479	3.7	0.04
1985	453	13.2	0.60	0.07	653	4.5	0.06
1986	574	13.6	0.74	0.08	875	5.5	0.08
1987	956	16.7	1.14	0.14	1,308	7.1	0.11
1988	914	14.1	0.96	0.12	1,632	7.8	0.13
1989	1,252	15.6	1.23	0.16	2,136	8.9	0.17
1990	1,293	14.6	1.28	0.17	2,549	9.5	0.19
1991	1,598	16.2	1.63	0.21	3,113	10.5	0.23
1992	2,321	20.1	2.46	0.31	4,060	12.1	0.30
1993	2,391	19.2	2.55	0.31	4,845	13.1	0.35
1994	3,116	22.0	3.01	0.38	6,041	14.6	0.43
1995	4,102	25.9	3.81	0.49	7,718	16.7	0.53
1996	5,696	30.9	5.05	0.67	10,171	19.4	0.69
1997	7,211	32.0	5.50	0.82	13,390	22.1	0.88
1998	11,099	40.6	8.02	1.21	18,838	26.8	1.20
1999	15,276	45.1	10.16	1.58	26,535	32.2	1.64
2000	18,661	48.1	11.83	1.83	35,445	37.0	2.14
2001	18,865	47.0	11.71	1.82	42,016	39.3	2.47
2002	19,664	50.4	12.43	1.84	47,474	41.8	2.73
2003	24,110	55.5	14.19	2.21	55,122	45.0	3.10
2004	27,901	55.8	15.41	2.47	63,995	47.6	3.51
2005	35,584	63.4	18.01	3.04	78,080	53.2	4.17
80-05	27.93	10.41	22.48	24.36	31.37	16.81	27.74
80-87	43.77	17.70	39.04	39.67	47.75	30.57	42.76
87-05	22.25	7.70	16.58	18.87	25.51	11.85	22.33
87-95	19.96	5.61	16.31	17.52	24.85	11.32	21.68
95-05	24.12	9.39	16.80	19.97	26.04	12.27	22.85
95-00	35.39	13.20	25.42	29.98	35.65	17.22	32.03
00-05	13.78	5.72	8.77	10.72	17.11	7.54	14.31

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Table 9: Chained Dollar (1997 base year) Communications ICT Investment and ICT Capital Stock for the Total Economy in Canada, 1980-2005

	Investment				Capital Stock		
	Communications ICT Investment, millions of chained 1997 dollars	Proportion of Communication ICT Investment in Total ICT Investment, per cent	Proportion of Communications ICT Investment in Total Non-residential Investment, per cent	Proportion of Communications ICT investment in GDP, per cent	Communication ICT Geometric End-year Net Stock, millions of chained 1997 dollars	Proportion of Communication ICT Capital Stock in Total ICT Capital Stock, per cent	Proportion of Cumminication ICT Capital Stock in Total Stock, per cent
	A	B	C	D	E	F	G
1980	2,175	154.1	3.27	0.38	12,813	164.8	1.38
1981	2,565	125.3	3.26	0.43	13,838	147.2	1.41
1982	2,337	116.0	3.28	0.41	14,460	137.5	1.42
1983	1,991	81.0	2.96	0.34	14,712	125.3	1.40
1984	2,194	73.2	3.14	0.35	15,097	115.2	1.40
1985	2,143	62.4	2.83	0.32	15,360	106.4	1.38
1986	2,339	55.7	3.03	0.35	15,729	98.2	1.37
1987	2,875	50.2	3.42	0.41	16,435	89.0	1.39
1988	3,392	52.5	3.55	0.46	17,479	83.8	1.43
1989	3,912	48.8	3.84	0.51	18,804	78.5	1.48
1990	4,221	47.8	4.17	0.55	20,235	75.3	1.55
1991	4,303	43.8	4.39	0.58	21,400	72.2	1.60
1992	4,654	40.3	4.92	0.62	22,978	68.6	1.68
1993	4,401	35.4	4.69	0.57	24,223	65.4	1.74
1994	4,220	29.8	4.08	0.52	25,366	61.4	1.79
1995	4,412	27.8	4.10	0.53	26,848	58.1	1.85
1996	4,454	24.1	3.95	0.53	28,541	54.4	1.93
1997	5,791	25.7	4.42	0.66	31,362	51.8	2.06
1998	5,337	19.5	3.86	0.58	33,582	47.9	2.14
1999	6,732	19.9	4.48	0.69	37,018	44.9	2.29
2000	8,355	21.5	5.30	0.82	41,999	43.8	2.53
2001	8,198	20.4	5.09	0.79	46,574	43.6	2.74
2002	7,136	18.3	4.51	0.67	49,434	43.5	2.85
2003	7,294	16.8	4.29	0.67	52,219	42.6	2.94
2004	9,014	18.0	4.98	0.80	56,373	41.9	3.09
2005	8,907	15.9	4.51	0.76	59,745	40.7	3.19
							1.81
80-05	5.80	-8.69	1.29	2.85	6.35	-5.44	3.41
80-87	4.07	-14.80	0.64	1.10	3.62	-8.42	0.12
87-05	6.48	-6.20	1.54	3.54	7.43	-4.26	4.71
87-95	5.50	-7.13	2.28	3.35	6.33	-5.19	3.63
95-05	7.28	-5.45	0.95	3.69	8.33	-3.50	5.59
95-00	13.62	-5.00	5.26	9.08	9.36	-5.49	6.45
00-05	1.29	-5.89	-3.17	-1.43	7.30	-1.47	4.74

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Table 10: ICT Investment Implicit Price Deflator for the Total Economy, Canada, 1980-2005

	Total ICT Investment Deflator	Computer ICT Investment Deflator	Communications ICT Investment Deflator	Software ICT Investment Deflator	Total Non-Residential Investment Deflator	GDP Deflator
1980	300	2,093	82	n.a	83	55
1981	278	1,405	82	140	87	61
1982	288	1,409	91	146	93	66
1983	252	997	97	146	94	69
1984	238	847	100	145	95	72
1985	222	699	103	146	97	74
1986	205	588	106	140	98	76
1987	188	470	107	138	99	79
1988	179	439	106	134	99	83
1989	162	361	103	127	101	87
1990	154	325	103	122	103	89
1991	137	249	98	119	101	92
1992	128	205	99	110	97	93
1993	126	197	99	108	99	94
1994	121	177	97	106	100	95
1995	113	152	93	103	100	97
1996	104	113	97	102	99	99
1997	100	100	100	100	100	100
1998	94	85	102	98	101	100
1999	86	68	101	97	99	101
2000	82	61	99	99	100	106
2001	80	55	101	101	100	107
2002	77	49	103	99	101	108
2003	69	40	95	93	97	111
2004	64	34	92	89	97	114
2005	59	29	91	86	96	117
	Average Annual Growth Rate, %					
80-05	-6.28	-15.68	0.40	-2.00*	0.55	3.11
80-87	-6.44	-19.20	3.83	3.25**	2.40	5.47
87-05	-6.22	-14.27	-0.90	-2.58	-0.15	2.21
87-95	-6.16	-13.18	-1.68	-3.52	0.24	2.62
95-05	-6.26	-15.12	-0.27	-1.82	-0.47	1.88
95-00	-6.21	-16.66	1.15	-0.79	-0.13	1.62
00-05	-6.32	-13.56	-1.68	-2.84	-0.82	2.14

Source: Table 1 to Table 9.
*Growth rate is for 81-04 instead of 80-04
**Growth rate is for 81-87 instead of 80-87

Table 11: ICT Capital Stock Implicit Price Deflator for the Total Economy, Canada, 1980-2005

	Total ICT Capital Stock Deflator	Computer ICT Capital Stock Deflator	Communications ICT Capital Stock Deflator	Software ICT Capital Stock Deflator	Total Non-Residential Capital Stock Deflator	GDP Deflator
	A	B	C	D	E	F
1980	205.3	2,699.3	97.0	n.a	64.2	54.5
1981	187.2	1,919.0	94.0	150.4	69.8	60.7
1982	204.9	1,837.4	107.1	156.7	75.1	65.9
1983	202.7	1,301.0	115.1	162.1	75.9	69.4
1984	199.5	1,071.3	119.1	158.4	77.8	71.8
1985	195.6	870.1	122.7	160.5	80.2	73.6
1986	189.0	700.7	125.9	151.8	82.2	75.6
1987	181.6	565.0	127.5	149.9	84.0	79.2
1988	173.8	495.3	125.7	144.8	86.8	82.8
1989	162.9	402.8	123.3	138.9	90.3	86.6
1990	157.2	354.0	123.1	134.3	93.0	89.2
1991	148.6	270.4	122.1	136.3	91.7	91.6
1992	134.1	220.0	115.3	119.2	90.7	92.8
1993	131.4	206.9	114.8	116.5	92.0	94.1
1994	124.4	184.6	109.7	113.7	94.6	95.2
1995	113.4	156.8	101.0	108.1	96.2	97.4
1996	103.1	115.4	98.9	102.0	98.0	99.0
1997	100.0	100.0	100.0	100.0	100.0	100.0
1998	95.2	83.4	99.9	97.5	101.9	99.6
1999	87.7	65.1	96.5	95.0	103.3	101.4
2000	83.9	55.8	94.0	97.2	106.3	105.5
2001	82.2	50.6	93.8	99.2	107.4	106.9
2002	80.2	45.2	94.6	98.6	109.0	108.1
2003	71.5	37.2	85.1	92.9	109.0	111.2
2004	67.0	31.8	81.6	90.2	112.6	114.1
2005	62.8	26.0	79.1	88.6	114.2	117.3
	Average Annual Growth Rate, %					
80-05	-4.63	-16.94	-0.81	-2.18*	2.33	3.11
80-87	-1.74	-20.02	3.98	-0.06**	3.93	5.47
87-05	-5.73	-15.71	-2.62	-2.88	1.72	2.21
87-95	-5.72	-14.80	-2.87	-4.00	1.70	2.62
95-05	-5.74	-16.44	-2.42	-1.97	1.73	1.88
95-00	-5.86	-18.67	-1.42	-2.11	2.01	1.62
00-05	-5.62	-14.14	-3.40	-1.83	1.44	2.14

Source: From Table 1 to Table 4 and Table 7 to Table 10.
*Growth rate is for 81-05 instead of 80-05
**Growth rate is for 81-87 instead of 80-87

Table 12: ICT and its Components Investment Per Worker and Capital Stock Per Worker in Canada by Industry, in current Canadian dollars, 2005

	Investment per worker				Capital Stock per worker			
	Total ICT Investment per worker in Canada	Computer ICT Investment per worker	Communication ICT Investment per worker	Software ICT Investment per worker	Total ICT Capital Stock per worker	Computer ICT Capital Stock per worker	Communication ICT Capital Stock per worker	Software ICT Capital Stock per worker
	A	B	C	D	E	F	G	H
Business Sector	2,128	650	567	911	6,007	1,240	3,250	1,518
Agriculture Forestry Fishing and Hunting	359	151	76	131	703	304	194	205
Mining and Oil and Gas Extraction	1,859	753	374	732	3,244	1,218	1,071	955
Utilities	12,892	3,793	n.a	n.a	32,681	7,682	n.a	n.a
Construction	250	194	n.a	56	680	565	n.a	115
Manufacturing	1,393	467	80	846	2,232	758	248	1,227
Wholesale Trade	3,260	1,060	130	2,070	5,541	1,831	605	3,105
Retail Trade	739	299	30	410	1,204	481	140	583
Transportation and Warehousing	1,974	592	290	1,093	4,638	1,287	1,412	1,939
Information and Cultural Industries	16,353	1,170	13,249	1,935	91,358	2,128	85,029	4,202
Finance and Insurance	6,413	1,600	436	4,378	13,972	3,863	2,394	7,714
Real Estate Rental and Leasing	7,920	3,785	608	3,527	15,474	6,763	3,032	5,680
Professional Scientific and Technical Services	2,510	1,225	737	549	5,476	2,310	2,362	804
Management of Companies and Enterprises	36,977	18,244	1,119	17,614	71,616	34,016	6,168	31,432
Administrative and Support	1,002	613	n.a	232	1,987	1,185	294	508
Educational Services	915	524	23	367	1,944	1,128	209	607
Health Care and Social Assistance	408	185	34	189	898	405	141	352
Arts Entertainment and Recreation	1,346	867	91	388	2,174	1,148	583	443
Accommodation and Food Services	257	114	n.a	n.a	271	127	n.a	n.a
Other Services(except Public. Admin.)	730	288	n.a	492	2,109	738	358	1,014
Public Administration	3,883	1,145	562	2,177	10,451	2,304	4,348	3,799

Source: CSLS ICT database based on Statistics Canada's unpublished data: Table 9a-w to 12a-w.

Note: ICT Investment includes investment in computers and peripheral equipment, software including own account software and communication equipment.

Table 13: Total Real ICT Capital Stock per Worker and its Components, Total Economy, chained $1997, 1987-2005

	Capital Stock						Capital Stock per Worker				
	Total Capital Stock, millions of chained 1997 dollars	ICT Capital Stock, millions of chained 1997 dollars	Computer ICT Capital Stock, millions of chained 1997 dollars	Communication ICT Capital Stock, millions of chained 1997 dollars	Software ICT Capital Stock, millions of chained 1997 dollars	Numbers of Workers, thousands of persons	Total Capital Stock per worker	ICT Capital Stock per worker	Computer ICT Capital Stock per worker	Communication ICT Capital Stock per worker	Software ICT Capital Stock per worker
	A	B	C	D	E	F	F = A/F	G = B/F	H = C/F	I = D/F	J = E/F
1987	1,180,193	18,461	1,308	16,435	3,457	12,333	95,694	1,497	106	1,333	280
1988	1,223,011	20,849	1,632	17,479	4,274	12,710	96,227	1,640	128	1,375	336
1989	1,267,856	23,943	2,136	18,804	5,198	12,996	97,556	1,842	164	1,447	400
1990	1,307,457	26,881	2,549	20,235	6,204	13,086	99,910	2,054	195	1,546	474
1991	1,340,463	29,657	3,113	21,400	6,990	12,857	104,256	2,307	242	1,664	544
1992	1,366,765	33,482	4,060	22,978	7,947	12,731	107,358	2,630	319	1,805	624
1993	1,389,892	37,036	4,845	24,223	9,315	12,793	108,647	2,895	379	1,894	728
1994	1,419,778	41,319	6,041	25,366	10,926	13,059	108,723	3,164	463	1,942	837
1995	1,449,862	46,191	7,718	26,848	12,166	13,295	109,050	3,474	581	2,019	915
1996	1,480,517	52,431	10,171	28,541	13,833	13,421	110,310	3,907	758	2,127	1,031
1997	1,523,612	60,558	13,390	31,362	15,806	13,706	111,164	4,418	977	2,288	1,153
1998	1,566,995	70,179	18,838	33,582	18,031	14,046	111,560	4,996	1,341	2,391	1,284
1999	1,613,813	82,419	26,535	37,018	20,256	14,407	112,018	5,721	1,842	2,570	1,406
2000	1,659,594	95,848	35,445	41,999	21,712	14,764	112,407	6,492	2,401	2,845	1,471
2001	1,701,928	106,864	42,016	46,574	23,095	14,946	113,870	7,150	2,811	3,116	1,545
2002	1,736,676	113,571	47,474	49,434	23,239	15,310	113,431	7,418	3,101	3,229	1,518
2003	1,777,272	122,554	55,122	52,219	24,464	15,672	113,402	7,820	3,517	3,332	1,561
2004	1,822,098	134,465	63,995	56,373	26,359	15,947	114,260	8,432	4,013	3,535	1,653
2005	1,873,060	146,809	78,080	59,745	27,755	16,170	115,838	9,079	4,829	3,695	1,716
	Average Annual Growth Rate, %										
87-05	2.60	12.21	25.51	7.43	12.27	1.52	1.07	10.53	23.63	5.83	10.59
87-89	3.65	13.88	27.79	6.96	22.62	2.65	0.97	10.94	24.49	4.20	19.45
89-00	2.48	13.44	29.10	7.58	13.88	1.17	1.30	12.13	27.61	6.34	12.57
00-05	2.45	8.90	17.11	7.30	5.03	1.84	0.60	6.94	15.00	5.37	3.14

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Table 14: Growth in Total Real ICT Capital Stock per Worker by Industry

	Capital Stock per worker, chained $1997			Average Annual Growth Rates, per cent		
	1987	2000	2005	1987-2005	1987-2000	2000-2005
Business Sector	1,684	6,691	9,385	10.02	11.20	7.00
Agriculture Forestry Fishing and Hunting	74	608	1,314	17.32	17.57	16.66
Mining and Oil and Gas Extraction	315	2,106	4,828	16.37	15.73	18.05
Utilities	2,964	34,940	61,172	18.31	20.90	11.85
Construction	108	1,124	1,982	17.55	19.75	12.01
Manufacturing	340	2,324	4,104	14.84	15.93	12.04
Wholesale Trade	553	6,904	9,137	16.87	21.44	5.76
Retail Trade	128	1,502	2,511	17.98	20.85	10.82
Transportation and Warehousing	466	5,418	7,748	16.90	20.77	7.42
Information and Cultural Industries	42,707	95,137	121,040	5.96	6.35	4.93
Finance and Insurance	2,931	16,465	22,048	11.86	14.20	6.01
Real Estate Rental and Leasing	2,148	14,840	26,499	14.98	16.03	12.29
Professional Scientific and Technical Services	417	7,355	12,982	21.06	24.71	12.04
Management of Companies and Enterprises	2	81,216	169,448	89.42	128.86	15.85
Administrative and Support	433	2,487	4,263	13.54	14.39	11.38
Educational Services	327	2,466	4,619	15.86	16.83	13.38
Health Care and Social Assistance	59	962	1,986	21.56	23.92	15.61
Arts Entertainment and Recreation	188	2,851	5,144	20.18	23.26	12.53
Accommodation and Food Services	45	167	541	14.79	10.59	26.46
Other Services(except Public. Admin.)	101	2,354	4,009	22.67	27.38	11.24
Public Administration	1,922	13,793	17,067	12.90	16.37	4.35
Total Economy	1,497	6,492	9,079	10.53	11.95	6.94

Source: CSLS ICT database based on Statistics Canada's unpublished data: Table 13a-w to 16a-w.

Note: ICT Investment includes investment in computers and peripheral equipment, software including own account software and communication equipment.

Table 15: Growth in Real Computer ICT Capital Stock per Worker by Industry

	Capital Stock per worker, chained $1997			Average Annual Growth Rates, per cent		
	1987	2000	2005	1987-2005	1987-2000	2000-2005
Business Sector	109	2,359	4,700	23.3	26.7	14.8
Agriculture Forestry Fishing and Hunting	6	270	1,159	34.5	34.8	33.8
Mining and Oil and Gas Extraction	28	417	4,525	32.7	23.2	61.1
Utilities	1,073	14,518	33,207	21.0	22.2	18.0
Construction	44	975	2,205	24.3	27.0	17.7
Manufacturing	68	1,354	3,061	23.6	25.9	17.7
Wholesale Trade	86	3,243	6,844	27.5	32.2	16.1
Retail Trade	19	750	2,132	30.1	32.8	23.2
Transportation and Warehousing	77	3,096	4,351	25.1	32.9	7.0
Information and Cultural Industries	254	3,554	8,815	21.8	22.5	19.9
Finance and Insurance	629	9,026	13,927	18.8	22.7	9.1
Real Estate Rental and Leasing	504	8,569	23,588	23.8	24.4	22.4
Professional Scientific and Technical Services	215	6,344	8,805	22.9	29.7	6.8
Management of Companies and Enterprises	1	48,556	150,357	97.0	134.5	25.4
Administrative and Support	152	1,918	4,189	20.2	21.6	16.9
Educational Services	78	1,609	4,796	25.8	26.3	24.4
Health Care and Social Assistance	19	717	1,512	27.6	32.4	16.1
Arts Entertainment and Recreation	29	1,911	5,411	33.6	37.9	23.1
Accommodation and Food Services	13	96	530	23.1	17.0	40.6
Other Services(except Public. Admin.)	36	1,338	2,842	27.5	32.1	16.3
Public Administration	179	5,318	9,397	24.6	29.8	12.1
Total Economy	106	2,401	4,829	23.6	27.1	15.0

Source: CSLS ICT database based on Statistics Canada's unpublished data: Table 13a-w to 16a-w.
Note: ICT Investment includes investment in computers and peripheral equipment, software including own account software and communication

Table 16: Growth in Real Communications ICT Capital Stock per Worker by Industry

	Capital Stock per worker, chained $1997			Average Annual Growth Rates, per cent		
	1987	2000	2005	1987-2005	1987-2000	2000-2005
Business Sector	1,526	3,098	4,111	5.7	5.6	5.8
Agriculture Forestry Fishing and Hunting	60	121	248	8.2	5.6	15.4
Mining and Oil and Gas Extraction	72	612	1,195	16.9	17.9	14.3
Utilities	n.a	n.a	n.a	n.a.	n.a.	n.a.
Construction	n.a	n.a	n.a	n.a.	n.a.	n.a.
Manufacturing	38	83	301	12.1	6.2	29.3
Wholesale Trade	22	457	673	21.0	26.3	8.1
Retail Trade	19	133	191	13.8	16.3	7.5
Transportation and Warehousing	246	698	1,441	10.3	8.4	15.6
Information and Cultural Industries	43,353	85,178	109,283	5.3	5.3	5.1
Finance and Insurance	330	1,371	2,604	12.2	11.6	13.7
Real Estate Rental and Leasing	654	2,644	3,441	9.7	11.3	5.4
Professional Scientific and Technical Services	115	491	2,727	19.2	11.8	40.9
Management of Companies and Enterprises	n.a	4,650	8,175	n.a.	n.a.	11.9
Administrative and Support	260	303	315	1.1	1.2	0.8
Educational Services	69	254	263	7.7	10.5	0.7
Health Care and Social Assistance	n.a	n.a	n.a	n.a.	n.a.	n.a.
Arts Entertainment and Recreation	112	919	835	11.8	17.6	-1.9
Accommodation and Food Services	n.a	n.a	n.a	n.a.	n.a.	n.a.
Other Services(except Public. Admin.)	26	382	408	16.5	23.0	1.3
Public Administration	1,435	5,106	5,431	7.7	10.3	1.2
Total Economy	1,333	2,845	3,695	5.8	6.0	5.4

Source: CSLS ICT database based on Statistics Canada's unpublished data: Table 13a-w to 16a-w.
Note: ICT Investment includes investment in computers and peripheral equipment, software including own account software and communication

Table 17: Growth in Real Software ICT Capital Stock per Worker by Industry

	Capital Stock per worker, chained $1997			Average Annual Growth Rates, per cent		
	1987	2000	2005	1987-2005	1987-2000	2000-2005
Business Sector	274	1,450	1,690	10.6	13.7	3.1
Agriculture Forestry Fishing and Hunting	23	212	234	13.6	18.5	1.9
Mining and Oil and Gas Extraction	225	1,057	1,070	9.0	12.6	0.2
Utilities	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Construction	76	201	140	3.4	7.8	-7.0
Manufacturing	265	1,000	1,365	9.5	10.8	6.4
Wholesale Trade	490	3,492	3,440	11.4	16.3	-0.3
Retail Trade	116	683	771	11.1	14.6	2.4
Transportation and Warehousing	229	1,705	2,063	13.0	16.7	3.9
Information and Cultural Industries	304	5,853	4,822	16.6	25.5	-3.8
Finance and Insurance	1,799	7,178	8,191	8.8	11.2	2.7
Real Estate Rental and Leasing	1,200	4,738	6,027	9.4	11.1	4.9
Professional Scientific and Technical Services	141	940	913	10.9	15.7	-0.6
Management of Companies and Enterprises	1	28,584	39,187	83.7	126.6	6.5
Administrative and Support	126	427	544	8.5	9.8	5.0
Educational Services	225	767	823	7.5	9.9	1.4
Health Care and Social Assistance	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Arts Entertainment and Recreation	59	336	602	13.8	14.3	12.4
Accommodation and Food Services	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other Services(except Public. Admin.)	54	658	1,135	18.4	21.2	11.5
Public Administration	646	3,891	4,443	11.3	14.8	2.7
Total Economy	280	1,471	1,716	10.6	13.6	3.1

Source: CSLS ICT database based on Statistics Canada's unpublished data: Table 13a-w to 16a-w.
Note: ICT Investment includes investment in computers and peripheral equipment, software including own account software and communication

Table 18: Shares of ICT Investment in Non-residential Fixed Capital Formation in Selected OECD Countries, Total Economy, 1990-2002

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Australia	12.5	14.2	15.7	16.6	18.1	18.2	18.7	18.8	20.3	21.0	22.5	23.2	21.4
Austria	10.0	10.1	9.4	10.1	11.1	10.4	10.8	11.3	13.3	13.8	13.1	13.0	..
Belgium	16.2	16.5	17.5	15.2	16.0	16.5	17.3		20.0	20.8	23.7	21.9	..
Canada	13.2	14.2	16.1	16.9	16.4	16.8	18.0	17.5	18.8	19.9	20.5	20.3	19.8
Denmark	17.7	18.2	19.0	20.5	18.7	20.7	20.5	21.2	20.7	21.6	19.9	20.3	..
Finland	9.1	10.6	13.5	17.2	20.2	22.2	18.8	22.3	25.3	27.5	30.9	28.1	..
France	7.8	7.5	7.6	8.1	8.6	9.0	9.8	11.0	11.9	12.2	12.8	13.2	13.7
Germany	13.9	13.7	13.2	13.3	13.2	13.3	14.2	14.7	15.3	16.5	17.4	17.8	16.5
Greece	9.4	11.6	11.7	16.1	14.3	12.7	13.2	13.2	15.1	15.3	16.7	18.2	..
Ireland	8.3	9.7	9.5	10.2	11.7	15.6	14.4	14.7	13.4	12.4	14.4	12.8	..
Italy	14.2	14.2	14.2	14.3	15.1	14.8	15.1	16.3	15.9	16.1	16.1	15.5	..
Japan	8.0	8.5	8.6	8.9	9.0	10.3	12.5	12.3	12.6	13.8	14.4	14.2	13.1
Netherlands	13.9	13.6	14.3	14.8	14.6	14.1	14.8	16.2	17.8	18.3	18.5	18.0	..
New Zealand	12.3	12.9	12.9	11.4	11.4	10.8	10.9	11.3	13.5	12.7	15.5	14.4	13.6
Portugal	10.4	11.6	11.5	11.5	11.5	12.5	12.8	11.9	11.8	11.7	11.8	12.0	..
Spain	12.0	11.5	11.2	11.5	11.8	9.6	11.2	10.9	10.9	10.8	11.2	10.7	..
Sweden	15.0	16.4	19.0	24.3	23.8	23.5	22.7	24.2	26.3	27.9	30.0	29.5	..
United Kingdom	13.8	14.4	15.1	16.6	18.3	20.7	21.1	20.2	23.1	22.1	23.5	21.9	..
United States	24.6	26.3	27.7	26.8	26.3	27.3	27.9	28.8	28.9	31.3	33.4	32.1	32.6

Source : OECD FACTBOOK 2005 – ISBN 92-64-01869-7 – © OECD 2005

Table 19: Contribution of ICT Capital to Labour Productivity Growth by Industry, 1987-2005

		Absolute contributions (percentage points per year)				Relative contributions (Per cent per year)			
	Labour productivity growth, per cent per year	Total ICT contribution	Computer ICT contribution	Communications ICT contribution	Software ICT contribution	Total ICT contribution	Computer ICT contribution	Communications ICT contribution	Software ICT contribution
Business Sector	1.51	0.21	0.10	0.07	0.05	13.9	6.8	4.5	3.3
Agriculture Forestry Fishing and Hunting	2.71	0.03	0.02	0.00	0.01	1.2	0.8	0.2	0.3
Mining and Oil and Gas Extraction	1.86	0.01	0.01	0.00	0.00	0.7	0.4	0.2	0.2
Utilities	0.51	0.12	0.05	n.a.	n.a.	24.4	10.7	n.a.	n.a.
Construction	0.14	0.09	0.09	n.a.	0.01	65.6	61.7	n.a.	4.1
Manufacturing	2.35	0.11	0.07	0.01	0.04	4.7	2.8	0.2	1.7
Wholesale Trade	2.83	0.58	0.30	0.04	0.24	20.3	10.7	1.4	8.6
Retail Trade	1.17	0.16	0.10	0.01	0.06	14.1	8.8	0.9	4.7
Transportation and Warehousing	1.62	0.07	0.04	0.01	0.02	4.3	2.4	0.6	1.3
Information and Cultural Industries	4.42	1.15	0.12	0.96	0.11	26.0	2.7	21.6	2.4
Finance and Insurance	n.a.	1.19	0.61	0.13	0.50	n.a	n.a	n.a	n.a
Real Estate Rental and Leasing	n.a.	0.23	0.15	0.03	0.06	n.a	n.a	n.a	n.a
Professional Scientific and Technical Services	0.95	1.95	1.41	0.24	0.20	206.4	149.0	25.8	21.4
Management of Companies and Enterprises	n.a.	4.00	2.21	0.12	1.67	n.a	n.a	n.a	n.a
Administrative and Support	-1.41	0.75	0.67	0.01	0.11	-53.3	-47.2	-0.8	-7.5
Educational Services	-1.21	0.03	0.02	0.00	0.00	-2.1	-1.7	-0.1	-0.4
Health Care and Social Assistance	-0.59	0.04	0.03	n.a	n.a	-6.2	-4.3	n.a	n.a
Arts Entertainment and Recreation	-1.01	0.16	0.11	0.04	0.02	-16.0	-10.8	-3.6	-2.3
Accommodation and Food Services	-0.47	0.02	0.02	n.a	n.a	-5.1	-3.6	n.a	n.a
Other Services(except Public. Admin.)	2.95	0.25	0.15	0.03	0.08	8.6	5.0	0.9	2.6
Public Administration	1.14	0.08	0.04	0.02	0.02	7.0	3.4	1.8	1.8
Total Economy	1.25	0.19	0.10	0.06	0.05	15.3	7.7	4.6	3.7

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Note: Labour productivity is defined as output per worker. These calculation are based on a simple growth accounting methodology where the contribution of ICT capital to labour productivity growth is equal to the product of the rate of growth of ICT capital intensity and the share of ICT capital in income. The latter is calculated as the product of capital share of income (1 minus the share of labour compensations) and the ICT capital share of total capital. Period averages are used. Over the 1987-2005 period, the ICT capital share was 0.02. It is important to note that the capital stock, not the capital services, were used because of data constraints.

Table 20: Contribution of ICT Capital to Labour Productivity Growth by Industry, 1996-2000

		Absolute contributions (percentage points per year)				Relative contributions (Per cent per year)			
	Labour productivity growth, per cent per year	Total ICT contribution	Computer ICT contribution	Communications ICT contribution	Software ICT contribution	Total ICT contribution	Computer ICT contribution	Communications ICT contribution	Software ICT contribution
Business Sector	2.76	0.28	0.15	0.09	0.04	10.1	5.4	3.3	1.5
Agriculture Forestry Fishing and Hunting	4.42	0.04	0.02	0.00	0.01	0.8	0.4	0.1	0.2
Mining and Oil and Gas Extraction	4.81	0.02	0.01	0.01	0.00	0.3	0.1	0.1	0.1
Utilities	2.98	0.21	0.10	n.a.	n.a.	7.2	3.5	n.a.	n.a.
Construction	1.25	0.08	0.10	n.a.	-0.02	6.1	8.1	n.a.	-1.3
Manufacturing	3.57	0.11	0.11	0.00	0.01	3.1	3.0	0.1	0.3
Wholesale Trade	1.86	0.67	0.37	0.11	0.24	36.1	20.1	5.8	12.8
Retail Trade	2.13	0.12	0.06	0.02	0.04	5.4	2.9	0.8	2.1
Transportation and Warehousing	0.75	0.18	0.10	0.03	0.05	24.0	13.6	3.5	6.5
Information and Cultural Industries	8.06	1.54	0.04	1.26	0.18	19.1	0.5	15.6	2.2
Finance and Insurance	n.a.	2.10	1.78	0.14	0.44	n.a	n.a	n.a	n.a
Real Estate Rental and Leasing	n.a.	0.18	0.19	0.01	0.02	n.a	n.a	n.a	n.a
Professional Scientific and Technical Services	6.63	1.73	1.78	0.02	-0.01	26.1	26.9	0.3	-0.2
Management of Companies and Enterprises	n.a.	3.65	2.89	n.a.	1.01	n.a	n.a	n.a	n.a
Administrative and Support	-5.39	0.50	0.66	-0.06	-0.03	-9.2	-12.2	1.1	0.5
Educational Services	-1.71	0.03	0.03	0.00	0.00	-2.0	-2.0	-0.1	-0.2
Health Care and Social Assistance	-0.22	0.05	0.04	n.a	n.a	-23.4	-19.4	n.a	n.a
Arts Entertainment and Recreation	0.53	0.26	0.26	0.05	0.01	48.2	49.5	9.6	2.0
Accommodation and Food Services	1.39	0.01	0.02	n.a	n.a	0.9	1.1	n.a	n.a
Other Services(except Public. Admin.)	7.70	0.20	0.12	0.04	0.04	2.6	1.6	0.5	0.5
Public Administration	3.16	0.09	0.05	0.02	0.03	2.8	1.5	0.7	0.8
Total Economy	2.35	0.25	0.14	0.07	0.04	10.5	5.8	3.1	1.7

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Note: Labour productivity is defined as output per worker. These calculation are based on a simple growth accounting methodology where the contribution of ICT capital to labour productivity growth is equal to the product of the rate of growth of ICT capital intensity and the share of ICT capital in income. The latter is calculated as the product of capital share of income (1 minus the share of labour compensations) and the ICT capital share of total capital. Period averages are used. Over the 1987-2005 period, the ICT capital share was 0.02. It is important to note that the capital stock, not the capital services, were used because of data constraints.

Table 21: Contribution of ICT Capital to Labour Productivity Growth by Industry, 2000-2005

		Absolute contributions (percentage points per year)				Relative contributions (Per cent per year)			
	Labour productivity growth, per cent per year	Total ICT contribution	Computer ICT contribution	Communications ICT contribution	Software ICT contribution	Total ICT contribution	Computer ICT contribution	Communications ICT contribution	Software ICT contribution
Business Sector	1.03	0.15	0.07	0.07	0.01	14.3	6.3	6.7	1.4
Agriculture Forestry Fishing and Hunting	2.92	0.03	0.02	0.01	0.00	1.1	0.7	0.3	0.0
Mining and Oil and Gas Extraction	-2.39	0.02	0.01	0.00	0.00	-0.6	-0.5	-0.1	0.0
Utilities	-0.97	0.08	0.05	n.a.	n.a.	-8.3	-4.8	n.a.	n.a.
Construction	0.71	0.06	0.06	n.a.	-0.01	8.9	8.9	n.a.	-1.7
Manufacturing	1.00	0.09	0.05	0.01	0.03	9.0	5.1	1.3	2.7
Wholesale Trade	2.76	0.20	0.18	0.01	-0.01	7.1	6.4	0.5	-0.2
Retail Trade	2.22	0.10	0.08	0.01	0.01	4.5	3.6	0.3	0.5
Transportation and Warehousing	2.05	0.03	0.01	0.01	0.01	1.5	0.5	0.7	0.3
Information and Cultural Industries	3.58	0.95	0.11	0.93	-0.02	26.6	3.1	25.9	-0.7
Finance and Insurance	-0.25	0.60	0.29	0.15	0.15	-237.6	-114.9	-58.4	-60.4
Real Estate Rental and Leasing	0.99	0.19	0.15	0.02	0.03	19.4	14.7	1.6	3.1
Professional Scientific and Technical Services	-0.24	1.12	0.42	0.52	-0.01	-466.0	-174.1	-217.4	4.5
Management of Companies and Enterprises	n.a.	0.71	0.58	n.a.	0.13	n.a	n.a	n.a	n.a
Administrative and Support	0.51	0.63	0.56	0.01	0.06	123.2	108.3	1.6	12.1
Educational Services	-1.11	0.02	0.02	0.00	0.00	-1.9	-1.7	0.0	-0.1
Health Care and Social Assistance	-0.55	0.03	0.01	n.a	n.a	-4.8	-2.7	n.a	n.a
Arts Entertainment and Recreation	-1.00	0.10	0.08	-0.01	0.02	-10.1	-7.6	0.6	-2.1
Accommodation and Food Services	-0.56	0.04	0.03	n.a	n.a	-7.5	-5.2	n.a	n.a
Other Services(except Public. Admin.)	3.07	0.13	0.09	0.00	0.05	4.1	2.8	0.1	1.6
Public Administration	0.53	0.03	0.02	0.00	0.00	5.0	3.6	0.6	0.9
Total Economy	0.82	0.13	0.06	0.05	0.01	15.4	7.5	6.4	1.7

Source: CSLS ICT database based on Statistics Canada's unpublished data.

Note: Labour productivity is defined as output per worker. These calculation are based on a simple growth accounting methodology where the contribution of ICT capital to labour productivity growth is equal to the product of the rate of growth of ICT capital intensity and the share of ICT capital in income. The latter is calculated as the product of capital share of income (1 minus the share of labour compensations) and the ICT capital share of total capital. Period averages are used. Over the 1987-2005 period, the ICT capital share was 0.02. It is important to note that the capital stock, not the capital services, were used because of data constraints.

Table 22: Business Enterprise Research and Development Expenditures, All Industries and ICT Sectors, Current Dollars
1994-2006

	All industries	ICT*	ICT as a Share of Total
1994	7,567	2,857	37.8
1995	7,991	3,118	39.0
1996	7,997	3,207	40.1
1997	8,739	3,526	40.3
1998	9,682	4,123	42.6
1999	10,400	4,385	42.2
2000	12,395	6,056	48.9
2001	14,272	6,635	46.5
2002	13,516	5,268	39.0
2003	13,704	5,366	39.2
2004	14,441	5,501	38.1
2005	14,655	5,697	38.9
2006	14,850	5,730	38.6
	Average Annual Growth Rate		Percentage Point Change
94-05	6.19	6.48	1.12
94-00	8.57	13.34	11.10
00-05	3.41	-1.21	-9.98
94-06	5.78	5.97	0.18
00-06	3.06	-0.92	-3.86

Source : Cansim series V29793120 and V29793172.

* The NAICS codes included in the information and communications technologies (ICT) sector are: Commercial and Service Industry Machinery Manufacturing (3333), Computer and Peripheral Equipment Manufacturing (33411), Telephone Apparatus Manufacturing (33421), Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing (33422), Audio and Video Equipment Manufacturing (33431), Semiconductor and Other Electronic Component Manufacturing (33441), Navigational, Measuring, Electromedical, and Control Instruments Manufacturing (33451), Communication and Energy Wire and Cable Manufacturing (33592), Computer and Communications Equipment and Supplies Wholesaler-Distributors (4173), Office and Store Machinery and Equipment Wholesaler-Distributors (41791), Software Publishers (5112), Telecommunications (517), Internet Service Providers, Web Search Portals, and Data Processing Services (518), Office Machinery and Equipment Rental and Leasing (53242), Computer Systems Design and Related Services (5415) and Electronic and Precision Equipment Repair and Maintenance (8112)

Table 23: Contributions to GDP Growth, in OECD Countries, Total Economy, 1990-95 and 1995-2002[1]

In percentage points, based on cost shares and harmonised ICT price indices

	Australia	Canada	France	Germany	Italy	Japan	United Kingdom	United States
1990-95								
Labour input	0.87%	0.27%	-0.58%	-0.76%	-1.41%	-0.55%	-0.79%	0.91%
ICT capital, of which	0.54%	0.34%	0.18%	0.33%	0.20%	0.37%	0.49%	0.53%
ICT hardware	*0.31%*	*0.17%*	*0.08%*	*0.19%*	*0.09%*	*0.23%*	*0.27%*	*0.26%*
Software	*0.17%*	*0.12%*	*0.05%*	*0.08%*	*0.03%*	*0.09%*	*0.19%*	*0.19%*
Communications equipment	*0.06%*	*0.05%*	*0.04%*	*0.06%*	*0.08%*	*0.05%*	*0.04%*	*0.09%*
Non-ICT capital	0.38%	0.63%	0.60%	0.67%	0.60%	0.94%	0.64%	0.22%
MFP	1.41%	0.45%	0.86%	1.05%	1.87%	0.74%	1.31%	0.79%
GDP growth	3.19%	1.70%	1.06%	1.29%	1.26%	1.50%	1.65%	2.45%
1995-2002[1]								
Labour input	0.86%	1.40%	0.13%	-0.18%	0.67%	-0.70%	0.67%	0.86%
ICT capital, of which	0.87%	0.60%	0.36%	0.42%	0.50%	0.57%	0.82%	0.86%
ICT hardware	*0.49%*	*0.37%*	*0.16%*	*0.28%*	*0.24%*	*0.36%*	*0.52%*	*0.44%*
Software	*0.14%*	*0.14%*	*0.13%*	*0.09%*	*0.12%*	*0.12%*	*0.20%*	*0.27%*
Communications equipment	*0.14%*	*0.09%*	*0.07%*	*0.06%*	*0.15%*	*0.08%*	*0.09%*	*0.15%*
Non-ICT capital	0.46%	0.62%	0.39%	0.48%	0.66%	0.57%	0.65%	0.31%
MFP	1.52%	1.01%	1.48%	0.68%	0.04%	0.56%	0.85%	1.24%
GDP growth	3.71%	3.64%	2.35%	1.41%	1.88%	1.00%	2.99%	3.27%
Change 1990-95 to 1995-2002[1]								
Labour input	-0.01%	1.13%	0.70%	0.57%	2.08%	-0.14%	1.46%	-0.05%
ICT capital, of which	0.33%	0.26%	0.18%	0.09%	0.29%	0.19%	0.33%	0.33%
ICT hardware	0.18%	0.20%	0.08%	0.09%	0.14%	0.13%	0.26%	0.18%
Software	-0.02%	0.03%	0.08%	0.01%	0.08%	0.03%	0.01%	0.08%
Communications equipment	0.08%	0.03%	0.02%	-0.01%	0.07%	0.03%	0.06%	0.06%
Non-ICT capital	0.08%	-0.01%	-0.21%	-0.19%	0.06%	-0.37%	0.01%	0.10%
MFP	0.11%	0.56%	0.62%	-0.36%	-1.83%	-0.18%	-0.46%	0.45%
GDP growth	0.51%	1.94%	1.30%	0.12%	0.61%	-0.50%	1.33%	0.82%

Source: Pilat, Dirk (2005) "Canada Productivity Performance in International Perspective", International Productivity Monitor, no.10, Spring 2005, p.24-44

Note 1: 1991-1995 for Germany; 1992-95 for France and Italy and 1993-1995 for Korea; 1995-99 for Korea and Portugal, 1995-2000 for Ireland, Spain and Switzerland, 1995-2001 for France, Germany, Hungary, Japan, Mexico, the Netherlands, Norway, Sweden, the United Kingdom and the United States.