Editor's Overview

THIS 26TH ISSUE OF THE *International Productivity Monitor* features articles on the following topics: the role of weak demand in explaining slower productivity growth; the sectoral productivity performance of Ontario industries; the sensitivity of multifactor productivity growth in Canada and the United States to alternative methodologies and assumptions; the role of measurement issues in explaining the Canada-U.S. ICT investment gap; the potential contribution of firm-level data to productivity analysis; and policies to improve government productivity performance.

Both output and productivity growth have been weaker in Canada since 2000 than in earlier decades. In the lead article, **Someshwar Rao** from S. Rao Consulting Inc. and **Jiang Li** from the University of Victoria find that this weaker output growth, reflecting weaker demand growth, was in fact largely responsible for slower productivity growth. Their econometric analysis shows that weaker demand reduces labour productivity growth through a number of channels, including fewer economies of scale and scope, weaker investment, and slower human capital formation.

The results of this analysis are relevant for the current policy debate on productivity for two reasons. First, they highlight the importance of robust demand for productivity growth. Policies that restrict demand growth, such as cuts in government spending, can have negative implications for productivity. Second, in the long term the expected slower population growth in Canada and weaker growth in our trading partners bode poorly for demand growth and hence productivity growth in this country.

Canada's poor productivity performance in the 2000s has been particularly acute in Ontario, which has experienced no labour productivity growth since 2005. In the second article, **Peter Spiro** from the University of Toronto provides a detailed sectoral analysis of productivity developments in Ontario. He reaches a similar conclusion to Rao and Li—demand matters for productivity. Using an instrumental variable approach, his econometric results show that the fall in productivity growth in manufacturing was due to a fall in output growth, reflecting falls in demand due to the appreciation of the Canadian dollar and the economic crisis in the United States.

Estimates of multifactor productivity (MFP) growth are sensitive to the methodologies and assumptions upon which these estimates are based. The symposium on multifactor productivity in Canada published in the Fall 2012 issue of the *International Productivity Monitor* highlighted this reality. In the third article in this issue, **Jiang Li** from the University of Victoria and **Larry Shute** and **Jianmin Tang** from Industry Canada make a further contribution to this debate by examining the sensitivity of MFP growth in Canada and the United States to alternative methodologies related to depreciation rates (Statistics Canada assumption versus Bureau of Economic Analysis assumption); rates of return (nominal versus real); and aggregation approaches (bottom-up versus top-down). They conclude that MFP growth estimates are fairly robust within both countries to the alternative methodologies and assumptions, with no effect on the MFP growth gap between the countries.

It is well known that Canadian firms invest much less in information and communication technologies (ICT) than their American counterparts and that this shortfall is an important factor explaining the Canada-U.S. productivity gap. But the reasons for this shortfall are not fully understood. An obvious explanation is that ICT investment is measured differently by the statistical agencies in the two countries. In the fourth article, **Vikram Rai** and **Andrew Sharpe** from the Centre for the Study of Living Standards find that measurement issues play only a small role in accounting for the gap. They find that almost all of the gap is in software and is concentrated in a relatively small number of sectors, especially information and cultural industries, and professional, scientific and technical services.

Productivity analysis has largely been conducted at the aggregate and industry levels. The increasing availability and accessibility of firm-level data from Statistics Canada now allows a greater number of productivity researchers to conduct their analysis at a more micro level. In the fifth article, **Don Drummond** from Queen's University, **Annette Ryan** from Employment and Social Development Canada and **Michael Veall** from McMaster University make the case that more firm-level productivity research is needed. They argue that this type of research can potentially shed much light on Canada's puzzle of weak productivity growth despite the adoption of market-friendly economic policies. To foster this type of research, they have established the Network to Study Productivity in Canada from a Firm-Level Perspective.

Productivity analysis is largely confined to business sector industries because of measurement problems in the non-business sector. This can lead to the neglect of the productivity issue in the public sector, where productivity improvement is equally important. In the sixth and final article, **Aled ab Iorwerth** from the Council of Canadian Academies contributes a review article on the new book *Growing the Productivity of Government Services* by Patrick Dunleavy and Leandro Carrera. Based on detailed case studies in the UK public sector, the authors of the book argue that the use of the latest information technology, combined with strong management skills, promise potential for considerable productivity advance in the public sector. However, quantifying these productivity gains requires better reporting on the various types of output governments produce.

Explaining Slower Productivity Growth: The Role of Weak Demand Growth

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Abstract

Using panel data on Canadian industries and OECD countries, this article examines empirically the role of growth in domestic and external demand in labour productivity growth. The findings suggest that most of the post-2000 slowdown in business sector labour productivity growth was the result of weak demand growth, which impacts productivity directly by reducing economies of scale and scope and by affecting key productivity drivers such as investment and R&D. With an expected slowdown in both domestic demand growth in Canada and external demand growth for Canadian exports, the medium- to long-term outlook for productivity growth, and hence for real income growth of Canadians, is expected to be weak.

Canada's business sector labour productivity growth increased at a meager 0.8 per cent per year since 2000, slightly over half of the pace registered during the 1981-2000 period. Productivity research has largely focused on supply-side explanations of this slowdown. In our view, the role of weaker demand conditions as a causal factor in this development has not received the attention it deserves. The objective of this article is to examine the linkages between demand and productivity growth in both Canada and OECD countries.

Labour productivity growth in Canada's manufacturing and service industries has lagged considerably behind their U.S. counterparts (Rao, 2011, and Sharpe, 2010). The dramatic slowdown in Canada's manufacturing exports and real output, largely due to the economic slowdown in the United States and Western Europe and the large real appreciation of the Canadian dollar vis-à-vis the U.S. dollar and other major currencies, seems to have contributed significantly to Canada's weak business sector labour productivity growth since 2000.

Economists and policy analysts analyze trend labour productivity growth mostly from the supply-side prism. The impact of demand on labour productivity growth is analyzed primarily in terms of their cyclical effects, via changes in the utilization rates for capital and labour.

The recent performance of Canada's manufacturing sector, the economic record of Japan, over the last two decades, and the recent economic performance of Western European coun-

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tries and emerging Asian economies strongly suggest a positive relationship between demand conditions and trend labour productivity growth. Therefore, it is important to empirically examine the linkages between demand conditions and trend labour productivity growth.

The article undertakes an empirical analysis of the potential linkages between trend productivity growth and demand conditions, drawing on the experiences at home and abroad, and examines the potential policy implications of our research findings.

This study addresses the following three key policy research questions:

- What are the key channels through which domestic and external demand conditions could influence trend labour productivity growth?
- What is the empirical evidence (both Canadian and foreign) on the impact of demand conditions on the key determinants of trend labour productivity growth? and;
- What are the potential policy implications of our new research findings?

Towards these goals, we draw on the existing research as well as undertake two types of new empirical research. First, we estimate the Verdoorn labour productivity growth equation using panel data for 35 Canadian two/three-digit NAICS industries and the aggregate data on all 34 OECD countries. Next, using the same two data sets, we regress some of the key drivers of productivity growth on two demand variables: growth in the domestic deamnd and growth in external demand.

The article is organized in five main sections. In the first section, we briefly discuss the importance of labour productivity growth for improvements in real incomes, quality of life and competitiveness in the medium- to long-term and examine the key determinants of labour productivity growth. In the second section, we discuss the channels through which domestic and external demand conditions can affect trend labour productivity growth. In the third section, we present the results from our empirical research on Verdoorn's Law. In the fourth section, we our findings on the linkages between growth in domestic and external demand and some of the key drivers of productivity growth: the investment/GDP ratio and the R&D/GDP ratio. In the last section, we summarize our key research findings and examine their policy implications as well as provide some suggestions for further research on this important topic.

Our empirical findings strongly suggest that a slowdown in domestic and external demand and economic activity sets in motion a vicious cycle of a slowdown in labour productivity, real GDP and real incomes. On the other hand, an increase in domestic and external demand and the ensuing economic activity would create a virtuous circle of an increase in the growth rate of labour productivity, real GDP and real incomes.

Labour Productivity Growth: Importance and Determinants

Productivity is the best overall indicator of a nation's underlying economic health. Over the long term, growth rates in real wages and real incomes in a country are mainly determined by trend labour productivity growth.

Labour productivity and quality of life also go hand in hand, because higher real incomes allows countries to invest more in health, education, environment and physical, telecommunication and knowledge infrastructures, and boost spending on social programs (Rao, 2011).

In the future, productivity growth will be more important to Canada 's economic growth than in the past decade for three key reasons.

First, because of the expected slowdown in working-age population growth and population ageing, Canada's labour force is expected to grow at a much slower pace than in the past 10 years.

Between now and 2020 the labour force is projected to increase at an average rate of 0.5 per cent per year, and could register a small negative growth thereafter. This means that the predominant source of economic growth and real income improvements in the future will be labour productivity growth.

Second, a significant part of the boost to Canada' real incomes in the post-2000 period came from terms of trade gains. This source is expected to disappear over the medium to long term, because it is highly unlikely that real commodity prices will keep on rising in the future.

Finally, to meet more effectively the growing competitive challenges from the United States and emerging economies, especially the BRIC countries, Canada needs to move up the value added chain and improve significantly its relative productivity performance, particularly in manufacturing and commercial services.

Both at the industry and aggregate levels, growth in labour productivity (real value added per hour worked) is equal to growth multifactor productivity (MFP) and the contribution from increases in capital intensity (the capital-labour ratio).

Growth in MFP captures the efficiency with which labour and capital are utilized in the production process. If capital and labour inputs are not adjusted for changes in quality over time, growth in MFP also captures changes in quality in factor inputs.[2]

Productivity research in Canada and in other countries indicates that growth in the aggregate productive efficiency, hence trend labour productivity growth, is mainly determined by scale and scope economies, improvements in human capital, innovation and innovation adoption (including international knowledge and technology transfers), as well as intra-firm and intra-industry shifts in productive inputs (for a detailed discussion, see Rao, 2011).

Impact of Demand Conditions on Key Productivity Drivers

A slowdown in domestic and external demand can create a vicious cycle of slower growth in labour productivity, real incomes and economic activity because of the negative impact of weaker demand on scale and scope economies, formation of physical and human capital, innovation and innovation adoption, entrepreneurial activity, and intra- and inter-industry shifts in productive resources.

Increasing Returns and Scale Economies

About fifty years ago, the Dutch economist P.J. Verdoorn published the results of his pioneering research on labour productivity growth and real output growth. His empirical results showed a significant positive relationship between the two variables. The real output growth coefficient for the labour productivity growth equation was around 0.5. Kaldor (1966) interpreted the strong positive relationship between the two variables as a reflection of the presence of both static and dynamic economies of scale and increasing returns. Since Kaldor's seminal work, the relationship between labour productivity growth and real output growth has been named as Verdoorn-Kaldor's Law.

Since the mid-sixties, this relationship has been examined in a large number of empirical studies, using a wide variety of data sets and employing different econometric models (e.g. Castiglione, 2011; and Libanio and Moro, 2009). Most of the empirical research to date reconfirmed the strong positive relationship between labour productivity growth and real

2 At the plant and firm levels, the appropriate concept of output for productivity analysis is gross output rather than value added, because of the importance of intermediate inputs in the production process at the micro level. In this framework, growth in labour productivity (real gross output per hour worked) will be equal to the contribution from growth in the capital-labour and the intermediate-labour ratios and growth in MFP.

output growth. Cointegration tests and Granger-causality analyses between these two variables generally confirm the presence of Verdoorn-Kaldor's Law, with causation running from change in output growh to change in productivity growth.

Human Capital

Human capital is a summary measure of educational attainment and the skills and experience of the labour force. It is a key determinant of productive efficiency and is a strong complement to the other key drivers of productivity, especially to innovation and innovation adoption.

A prolonged period of weak demand growth can negatively affect its human capital development via four important channels (Blanchard and Summers, 1989; Heckman and Masterov, 2007; Irons, 2009; and DeLong and Summers, 2012).

First, in a protracted period of slow growth in economic activity and weak job creation, the returns to human capital investments would be lower. This would impact negatively investment in higher education and skills development and upgrading. Second, increased family poverty arising from higher unemployment during a period of weaker economic growth could adversely impact childhood nutrition and cognitive development. A number of research studies have shown that early childhood education and cognitive capabilities are positively correlated with their lifetime educational and labour market performance. Hence, a prolonged period of slowdown in demand conditions could have long lasting adverse impact on human capital development and productivity. Third, increased long-term unemployment, especially among middle-aged and older workers, can make human capital obsolete and negatively affect overall productivity. Finally, an increase in unemployment from the slowdown in economic activity could raise the natural rate of unemployment via labour market "hysteresis", creating a vicious cycle of slowdown in economic activity and productivity.

Capital Accumulation

A prolonged period of weak demand conditions and economic activity can also negatively affect the accumulation of physical capital, that is investment in machinery and equipment (M&E) and structures, because of falling capacity utilization rates, and the decline in rates of return to investments. The most recent recession experience of the United States show that fixed investment as a share of potential output declined considerably in the post-2008 period compared to the pre-recession period (DeLong and Summers, 2012). Moreover, like human capital, some of the existing physical capital could also become obsolete from the prolonged slowdown in economic activity and the resulting structural adjustments.

In short, a protracted period of slowdown in demand conditions and economic activity would affect negatively capital accumulation and capital productivity, hence affecting overall productivity growth.

Innovation and Innovation Adoption

Likewise, a long-lasting demand slowdown has negative implications for innovation and innovation adoption because of the reduced returns to investments in R&D, the slow growth in foreign trade and foreign direct investment, the slowdown in new business formation and expansion, and the increased economic uncertainty and risk premiums.

Intra- and Inter-Industry Shifts in Productive Resources

The net impact of any slowdown in demand conditions on firm dynamics and aggregate labour productivity growth will depend on the magnitude of two opposing influences.

On the one hand, a slowdown in demand conditions could result in a slowdown of entrepreneurial activity, impacting negatively R&D spending and the adoption and diffusion of new knowledge and technologies.

On the other hand, during periods of weak economic activity, increased competitive pressures from home and abroad could increase the pace of creative destruction, that is the shift of productive resources from low productivity plants to high productivity plants, raising overall productivity growth.

As per inter-industry shifts in resources, during long periods of slowdown in demand conditions, capital and labour inputs are expected to shift from more productive tradable goods (in Canada's case mostly from manufacturing industries) and services to less productive non-tradable goods and services, with negative consequences for aggregate productivity growth.

In short, a prolonged slowdown in demand can negatively impact productivity performance via its adverse influence on scale and scope economies, investments in physical and human capital, innovation and innovation adoption, and intra- and inter-industry shifts in productive resources. In addition, the slowdown in economic activity and tax revenue and the increased spending on social programs can also reduce government spending on physical, knowledge and technology infrastructure.

The example of Japan illustrates dramatically the impact of slower economic growth on productivity growth (Table 1). In the 1981-90 period, before the Japanese financial crisis in 1991-92, total economy real output growth averaged 4.8 per cent per year and labour productivity growth averaged a very strong 4.1 per cent per year. In the 1991-2005 period after the crisis, real output growth fell to 1.3 per cent per year, and labour productivity growth to 0.5 per cent per year. The same trends were observed in Japan's manufacturing sector.

Table 1
Real Value Added, Labour Productivity and MFP in Japan, Before and After the 1991/92 Financial Crisis
(average annual growth rates, per cent)

Total Economy	1981-90	1991-2005
Real Value Added	4.8	1.3
Labour Productivity	4.1	1.5
MFP	1.7	0.1
Manufacturing Sector		
Real Value Added	6.7	0.9
Labour Productivity	6.2	2.0
MFP	3.9	0.5

Source: European Commission (2009).

Verdoorn's Labour Productivity Growth Equation

In the Verdoorn's labour productivity growth equation, the real output growth coefficient captures the impact of increasing returns and scale economies on the productive efficiency. We estimate two different Verdoorn productivity growth equations: one using panel data on 35 two/three–digit Canadian NAICS industries, and the other using the aggregate panel data on 34 OECD countries.[3]

Before estimating the Verdoorn productivity equation, we tested the data for non-stationarity and co-integration. Details on these tests are provided in Appendix 2.

Three different specifications of the Verdoorn's labour productivity growth are estimated. All three specifications control for industry (or country) fixed effects and time effects. To overcome issues related with the endogenous nature of real output growth and the capital intensity variables, we estimated all Verdoorn's productivity growth equations with instruments for these variables.

3 For details on data sources, see Appendix 1.

We used lagged GDP growth and capital intensity as well as the growth in domestic and external demand as instruments.

Verdoorn's Law

The dynamic panel model is similar to the VAR model; however we focus exclusively on the Verdoorn's effect, i.e. the real output growth coefficient. This means we are treating real output as an exogenous variable in our model. Panel-specific labour productivity is now modeled as:

(1) $\Delta LP_{it} = \beta_0 + \beta_{11}\,\Delta Y_{it} + \beta_{12}\Delta Y_{it-1} + \beta_{21}\Delta k_{it} + \beta_{22}\,\Delta k_{it-1} + \beta_3\,\Delta LP_{it-1} + \mu_{it}$

for $t = 2...T$ and $i = 1...N$ where N is the number of panels, i.e. 35 for Canadian industries and 34 for OECD countries, LP is labour productivity, Y is real output, and k is capital intensity (defined as capital stock per worker). Output denotes real value-added (RVA) for Canadian industries and real GDP for OECD countries. Different model specifications are considered where the base model assumes $\beta_{12} = \beta_{22} = \beta_3 = 0$, i.e. conventional Verdoorn. We allow for panel-specific fixed effects, since each panel is likely to have a different asymptotic growth rate, and for time effects to capture possible common business cycle fluctuations and technological advancement across all panels. These fixed effects and time effects can be removed using a first-differencing dynamic panel. However, this gives rise to endogeneity, and an instrumental variable approach is required to produce consistent estimates. This point is further discussed in Appendix 3.

Verdoorn Equation: Canadian Industries

As expected, in all 35 Canadian industries, the growth rates in labour productivity and real value added are highly correlated. The industry Verdoorn equation is estimated using data on 35 Canadian two/three-digit NAICS industries over the 1970-2008 period.

The average annual growth rate in real value added over the sample period varies a great deal across Canadian industries, from -3.5 per cent per year in leather and allied product manufacturing to almost 6.0 per cent per year in computer and electronic product manufacturing, and information and cultural industries. Similarly, the average labour productivity growth rate also varies considerably across Canadian industries, from almost -1.0 per cent in mining and oil and gas extraction to a 6.0 per cent growth rate in computer and electronic product manufacturing.

Empirical results are summarized in Table 2. The estimated coefficient for real output growth is positive and highly statistically significant, and the size of the coefficient is fairly stable between 0.74 and 0.92 in the first two equations, suggesting a very strong impact of real output growth on labour productivity growth. In the third model, the long-term coefficients for output growth and capital intensity growth are positive and statistically significant, and their magnitudes are reasonable: 0.65 and 0.16, respectively.[4]

Using the estimated long-term coefficient for real output growth in the Verdoorn equation, we can calculate how much of the post-2000 slowdown in labour productivity growth in Canada was caused by the slowdown in real output growth.

Real GDP in Canada grew at an average rate of 1.9 per cent per year between 2000 and 2012, down one percentage point from the average growth of 2.9 per cent per year experienced in the 1981-2000 period. During the same period, business sector labour productivity growth also fell, from 1.5 per

4 The long-term coefficient on real output growth is computed by adding the coefficients on its two lagged variables, and dividing the resulting value by 1.0 minus the coefficient on the lagged dependent variable. The long-term coefficent on capital intensity growth is computed in an analogous way. For example, the long-term coefficient on real output growth variable is equal to 0.65=[(0.810-0.356)/(1.0-0.304)]. The long-term coefficient on capital intensity growth variable is equal to 0.16=[(0.404-0.295)/(1.0-0.304)].

Table 2
Verdoorn's Effect in Canadian Industries: Dynamic General Moments of Method (GMM)

$$\Delta LP_{it} = \beta_0 + \beta_{11}\,\Delta RVA_{it} + \beta_{12}\,\Delta RVA_{it-1} + \beta_{21}\,\Delta k_{it} + \beta_{22}\,\Delta k_{it-1} + \beta_3\,\Delta LP_{it-1} + \varepsilon_t$$

	Model 1	Model 2	Model 3
	$\beta_{12} = \beta_{22} = \beta_3 = 0$	$\beta_{12} = \beta_{22} = 0$	full
ΔRVA_{it}	0.942***	0.923***	0.810***
	(26.998)	(27.385)	(33.986)
ΔRVA_{it-1}	..	..	-0.356***
	..	..	(-3.708)
Δk_{it}	0.512***	0.502***	0.404***
	(8.184)	(8.014)	(6.138)
Δk_{it-1}	..	..	-0.295***
	..	..	(-4.541)
ΔLP_{it-1}	..	-0.014	0.304***
	..	(-0.582)	(3.323)
H0: $\beta_{11} = 0$			
$\chi^2(1)$	728.881	749.965	
p-value	0.000	0.000	
H0: $\beta_{11} = \beta_{12} = 0$			
$\chi^2(2)$			1207.411
p-value			0.000
H0: $\beta_{11} + \beta_{12} = 0$			0.454
$\chi^2(1)$			20.058
p-value			0.000
Arellano-Bond test for AR(2) in differences (p-value)			
	0.276	0.250	0.352
No. of Obs.	1295	1260	1260
No. of Industries	35	35	35

Note: Sample is 1970-2008. Prior to reaching the regression specifications described above, several tests were performed, including the Hausman (1978) test for fixed/random effect, the likelihood ratio test for heteroskedasticity, the Wooldridge (2002) test for serial correlation, and the Breusch and Pagan (1980) Lagrange multiplier test for cross-section dependence. These tests suggest that the panel regression should account for heterogeneity, possible serial correlation and cross-industry dependence. Each model is estimated using a two-step feasible GMM with covariance correction derived by Windmeijer (2005). Time- and industry-fixed effects are included in each regression. Numbers in parentheses are t-statistics. *, ** , and *** denote 10%, 5% and 1% significance levels, respectively.

cent per year in 1981-2000 to 0.8 per cent per year in 2000-2012, a drop of 0.7 percentage points.

By multiplying the drop in real GDP growth between the two periods (1.0 percentage point) by the long-term coefficient for output growth in the Verdoorn equation (0.65), dividing the resulting value (0.65) by the drop in labour productivity growth between the two periods (0.7) and then multiplying the resulting estimate by 100, we find that the contribution of the fall in real output growth to the slowdown in business sector labour productivity growth between the two periods was 93 per cent = (0.65/0.70) * 100.

As discussed in the previous section, the Verdoorn coefficient in past studies varied between 0.4 and 0.5, compared to our estimate of 0.65 for the long-term real output growth impact on trend labour productivity growth.[5]

These results imply that an increase in real output growth would create a virtuous circle, leading to more labour productivity growth and therefore more real output growth. On the other hand, a decline in real output growth, either due to a slowdown in labour force growth and/or a slowdown in domestic and external demand would create a vicious cycle of slow growth in both real output and labour productivity.

Verdoorn Equation: OECD Countries

We estimated a Verdoorn equation using aggregate panel data on 34 OECD countries over the 1970-2010 period with the same three specifications as used in the Canadian equation.

The average annual real GDP growth varied from a low of 1.6 per cent in Switzerland to a high of 7.1 per cent in South Korea. Likewise, labour productivity growth varied from a low of 1.1 per cent in Switzerland to a high of 6.0 per cent in South Korea.

The estimated coefficient for real GDP growth is once again positive and highly statistically significant in all three specifications, and the size of the coefficient is fairly stable (between 0.98 and 0.99), suggesting a strong interdependence between the two variables (Table 3). Here too the long-term coefficient on the capital intensity growth proxy variable is positive, but is small and statistically insignificant.

The size of the Verdoorn coefficient is very large, strongly suggesting that it may be capturing much of the contributions of the growth in capital intensity and technical progress to labour productivity growth.

In short, the Verdoorn productivity growth equations for both Canada and the OECD countries as a whole show a strong interdependence between labour productivity growth and real output growth, suggesting significant scale economies and increasing returns. These results imply that a slowdown in labour force growth and domestic and external demand would have a significant negative impact on labour productivity growth in the medium to long term.

Estimating the Impact of Demand on Key Drivers of Labour Productivity Growth

As discussed in the previous section, changes in domestic and external demand conditions, in addition to impacting economic activity and labour productivity growth via scale economies and increasing returns (the Verdoorn effect), can also affect trend labour productivity growth through their effects on other key productivity drivers.

Demand conditions can be described as exogenous growth in domestic and external demand. This suggests a panel model with time- and panel-specific effects can be written as:

$$(2)\quad \dot{Y}_{it} = \eta_0 + \eta_1\, Domestic\dot{D}emand_{it} + \eta_3\, External\dot{D}emand_{it} + \varepsilon_{it}$$

for $t = 2...T$ and $i = 1...N$ where N is the number of panels, i.e. 15 for Canadian manufacturing industries, and 34 for OECD countries. Y denotes each of the key productivity drivers. For Canadian manufacturing industries, these key drivers are: gross fixed capital (GFC) formation, machinery and equipment (M&E) investment, information and communications technology (ICT) investment, and R&D expenditure by business enterprises. For the country-level analysis, the key drivers are GFC formation, M&E investment, and R&D. Once again we allow each panel to have a different asymptotic growth rate in the key productivity drivers. For the OECD analysis, we also include a year-specific effect to capture business cycle fluctuations.

5 To check for the robustness of the estimated coefficients, we estimated separate Verdoorn equations for only Canadian manufacturing industries. As expected, the estimated coefficients in all the three models are very similar to the ones for the full Canadian industry sample. However, the longer-term coefficients on the output growth and the capital intensity variables are slightly larger than in the full sample regressions.

Table 3

Verdoorn's Effect in OECD Countries: Dynamic General Moments of Method (GMM)

$$\Delta LP_{it} = \beta_0 + \beta_{11}\,\Delta GDP_{it} + \beta_{12}\,\Delta GDP_{it-1} + \beta_{21}\,\Delta k_{it} + \beta_{22}\,\Delta k_{it-1} + \beta_3\,L\Delta P_{it-1} + \varepsilon_t$$

	Model 1	Model 2	Model 3
	$\beta_{12} = \beta_{22} = \beta_3 = 0$	$\beta_{12} = \beta_{22} = 0$	full
ΔGDP_{it}	0.980***	0.985***	0.991***
	(89.885)	(76.847)	(73.769)
ΔGDP_{it-1}	..	..	-0.806***
	..	..	(-5.380)
Δk_{it}	0.011***	0.011***	0.002
	(3.023)	(2.989)	(0.474)
Δk_{it-1}	..	..	-0.002*
	..	..	(-1.719)
ΔLP_{it-1}	..	0.003	0.803***
	..	(0.496)	(5.239)
H0: $\beta_{11} = 0$			
$\chi^2(1)$	8079.315	5905.470	
p-value	0.000	0.000	
H0: $\beta_{11} = \beta_{12} = 0$			
$\chi^2(2)$			7337.360
p-value			0.000
H0: $\beta_{11} + \beta_{12} = 0$			0.185
$\chi^2(1)$			1.679
p-value			0.195
Arellano-Bond test for AR(2) in differences (p-value)			
	0.705	0.667	0.750
No. of Obs.	1154	1120	1120
No. of Countries	34	34	34

Note: Sample is 1970-2010. Prior to obtaining the regression specifications described above, several tests were performed, including the Hausman (1978) test for fixed/random effect, the likelihood ratio test for heteroskedasticity, the Wooldridge (2002) test for serial correlation,and the Breusch and Pagan (1980) Lagrange multiplier test for cross-section dependence. These tests suggest that the panel regression should account for heterogeneity, possible serial correlation and cross-industry dependence. Each model is estimated using a two-step feasible GMM with covariance correction derived by Windmeijer (2005). Time- and industry-fixed effects are included in each regression. Numbers in parentheses are t-statistics. *, ** , and *** denote 10%, 5% and 1% significance levels, respectively.

Separate regressions capture the impact of growth in domestic and external demand on each of the key drivers of productivity under the assumption that these key drivers are not correlated, and hence no serial correlation exists among residuals from each individual regression. This assumption is easily violated. ICT investment is part of M&E investment, which is part of GFC formation by definition; R&D expenditure may well translate investment efficiency into productivity, in which case the coefficient estimates are still unbiased yet inefficient. Structural equation modeling (SEM) relaxes such extreme assumptions and allows for non-zero covariances using quasi-maximum likelihood estimators that relax the normality assumptions when estimating standard errors. In the case of SEM, our left-hand-side variable becomes a vector of the key productivity drivers, i.e. Y = (GFC M&E ICT R&D)' for regressions on Canadian manufacturing and Y = (GFC M&E R&D)' for OECD analysis.

Domestic demand measures include real consumer expenditure, real investment in residential construction and real government spending (including government investment). External demand is proxied by real exports of goods and services.

External demand also impacts domestic spending. Therefore, some of the impact of external demand on the key drivers of productivity growth would be captured by the domestic demand variable. However, it is important to introduce separately the two demand variables, because the external demand variable, in addition to capturing the usual demand-side influences, is also likely to capture the impact of increases in product specialization, competitive pressures and international knowledge and technology flows on productivity growth. Of course, it is difficult to disentangle econometrically the influence of the two demand variables.

We estimated separate equations for GFC, M&E investment, ICT investment, and R&D spending, using the panel data on Canadian manufacturing industries. We also estimated equations for GFC, M&E and R&D, using the panel data on OECD countries. All the equations for the key drivers of productivity growth are estimated individually as well as a system of equations.

All the dependent and independent variables are in growth terms. All the equations take into account industry (or country) fixed effects and time specific effects.

For both Canadian manufacturing data and OECD data, the estimated coefficients in all equations are fairly robust. However, as expected, the standard errors are generally smaller for the system equation estimates.

Canadian Manufacturing Industries

As expected, the estimated coefficients for domestic and external demand are positive in all three investment equations, except the coefficient for domestic demand for ICT in the sytem equation (Table 4). None of the coefficients for domestic demand, however, were statistically significant at the 1 per cent level.

On the other hand, the coefficients for external demand are positive, stable, and highly statistically significant in all three investment equations. These results imply that the growth in external demand is very important for the growth in all three types of investments in Canadian manufacturing industries. This finding is not surprising given that the output growth in these industries depends heavily on demand for Canadian products in foreign markets.

It is important to note that the domestic demand variable is the same across all manufacturing industries, while the external demand variable varies across these industries. This could explain the lack of statistical significance of the domestic demand variable in the investment equations.

As expected, the coefficients for domestic and external demand are positive in the two R&D equations. However, they are not statistically significant.

OECD Countries

The estimated equations for all OECD countries are given in Table 4. In the GFC equations, the estimated coefficient for domestic demand is positive and highly statistically significant in the system equation but not in the individual equation. The coefficient for external demand is only marginally significant in the system equation and is not significant at all in the individul equation. As expected, the coefficient for domestic demand is much larger than the coefficient for external demand.

Table 4
Modeling the Impact of Demand on Key Productivity Drivers: Individual Panel Regression vs. Structural Equation Modeling (SEM)

$$\Delta Y_{it} = \beta_0 + \beta_1 \, \Delta DomesticDemand_{it} + \beta_2 \, \Delta ExternalDemand_{it} + \varepsilon_t$$

A) Canadian Manufacturing Industries (sample 1981-2011)

Dependent Variable, ΔY	GFC		M&E		ICT		R&D	
	Individual	SEM	Individual	SEM	Individual	SEM	Individual	SEM
$\Delta DomesticDemand_{it}$	2.694*	1.653	2.659**	1.772	1.299	-0.464	1.918	2.046
	(1.931)	(1.189)	(2.083)	(1.291)	(1.266)	(-0.359)	(1.564)	(1.393)
$\Delta ExternalDemand_{it}$	1.128***	1.457***	1.077***	1.469***	0.812*	1.056***	0.300	0.281
	(3.486)	(5.059)	(2.834)	(4.635)	(2.037)	(4.512)	(0.725)	(1.019)
Constant	-13.508**	-8.915*	-11.931**	-8.281	6.412	9.713**	-2.333	-2.708
	(-2.685)	(-1.693)	(-2.399)	(-1.582)	(1.403)	(2.117)	(-0.496)	(-0.529
No. of Obs.	450	250	450	250	450	250	250	250
No. of Industries	15	15	15	15	15	15	15	15

B) OECD Countries(sample 1970-2011)

	GFC		M&E		R&D	
Dependent Variable, ΔY	Individual	SEM	Individual	SEM	Individual	SEM
$\Delta DomesticDemand_{it}$	0.314	1.839***	2.054***	2.299***	0.564***	0.707***
	(0.370)	(11.943)	(7.301)	(6.477)	(3.736)	(2.896)
$\Delta ExternalDemand_{it}$	0.080	0.160*	0.273***	0.169*	0.125	0.169
	(0.631)	(2.465)	(2.951)	(1.941)	(0.664)	(1.090)
Constant	13.236***	-3.664**	-0.877	0.998	2.061	0.714
	(5.911)	(-2.105)	(-0.343)	(0.362)	(0.732)	(0.246)
No. of Obs.	848	419	750	419	439	419
No. of Countries	32	28	30	28	28	28

Note: All variables are annual growth rates. Prior to obtaining the regression specifications described above, several tests were performed, including the Hausman (1978) test for fixed/random effect, the likelihood ratio test for heteroskedasticity, the Wooldridge (2002) test for serial correlation,and the Breusch and Pagan (1980) Lagrange multiplier test for cross-section dependence. These tests suggest that the panel regression should account for heterogeneity, possible serial correlation and cross-industry dependence. Each model is estimated using a two-step feasible GMM with covariance correction derived by Windmeijer (2005). Time- and industry-fixed effects are included in each regression. Numbers in parentheses are t-statistics. *, ** , and *** denote 10%, 5% and 1% significance levels, respectively. Each individual regression model is estimated using Driscoll and Kraay (1998) standard errors, allowing for panel-specific fixed effect. The regressions examine the impact of growth in domestic and external demand on each of the key drivers of productivity under the assumption that these key drivers are not correlated by any means and hence there is no serial correlation among residuals from each regression. The structural equation modeling (SEM) captures such correlation and allows for non-zero covariances. SEM is estimated using quasi-maximum likelihood, which relaxes the normality assumptions for estimating standard errors and includes industry-specific (or country-specific) fixed effects. Numbers in parentheses are t-statistics. *, **, and *** denote 10%, 5% and 1% significance levels, respectively. Coefficients of fixed effects are not reported for space considerations.

Estimated coefficients on the two demand variables are positive and statistically significant in the M&E investment equation. Like GFC, the coefficient for domestic demand is more than ten times larger than the coefficient for external demand. Nevertheless, the coefficient on external demand in the system equation is barely statistically significant.

The coefficient for domestic demand is positive and highly statistically significant in the

R&D equation. Although positive, the coefficient for external demand is not statistically significant. This result is similar to the finding for Canadian manufacturing industries.

In short, our empirical analysis provides strong support to the proposition that the growth in domestic and external demand impacts positively the growth in gross fixed capital formation, M&E investment and R&D spending, some of the key drivers of productivity growth. These results and the findings on the Verdoorn labour productivity growth equation strongly suggest that demand conditions and trend labour productivity growth are highly interrelated.

Conclusion

Until now, economists almost exclusively analyzed productivity growth from the supply-side prism, ignoring the potential important interplay between demand conditions and trend labour productivity growth. The main objective of the article has been to examine empirically the impact of changes in economic activity and demand conditions at home and abroad on trend labour productivity growth. Towards this goal, we first estimated Verdoorn labour productivity growth equations using panel data on Canadian industries and OECD countries. Next, using the same data sets, we estimated the impact of domestic demand and external demand on key drivers of productivity growth: gross fixed capital formation, M&E investment, ICT investment and R&D spending.

Our major finding is that 93 per cent of the fall in average labour productivity growth between 1981-2000 and 2000-2012 can be attributed to the drop in real GDP growth between the two periods. Our estimates for the Verdoorn coefficient show a strong and robust positive inter-dependence between labour productivity growth, and real output growth, suggesting the presence of significant scale economies and increasing returns.

In addition, our new empirical research shows that a slowdown in growth of domestic and external demand also impacts negatively some of the key drivers of productivity growth—such as, gross fixed capital formation, M&E investment (including ICTs) and R&D spending—thus leading to lower trend labour productivity growth.

In short, our empirical findings strongly imply that the expected slowdown in demand in Canada, the United States, Japan, Europe and East Asia would negatively affect trend labour productivity growth in Canada, suggesting that the medium- to long-term outlook for real income growth in Canada could be fairly weak, with negative consequences for economic growth, government tax revenue and budget position, and spending on social programs.

The following are five key policy implications of our research findings:

- Government's medium- and long-term economic and budget planning should take into account the reality of slow growth in Canada's trend labour productivity (perhaps less than 1.0 per cent per year).
- Given the strong interplay between domestic demand and productivity, policy makers need to ensure that government deficit and debt reduction measures are gradual in nature, so that their adverse impact on domestic demand would not be excessive.
- Canada should offset some of the slowdown in demand for our goods and services in the United States and other major OECD economies by increasing exports to large and fast growing emerging economies such as China, India, Brazil, Indonesia, and South Africa. Comprehensive trade and investment agreements with these countries would be very helpful in this regard (Rao, 2012).

- Economic stimulus measures during periods of economic slowdown should mainly focus on increasing spending on key productivity drivers, in particular investment in both physical capital (especially M&E) and human capital and R&D spending.
- Policies and programs for reducing structural rigidities, improving resource allocation and functioning of the economy, and stimulating innovation and innovation adoption would also be helpful in moderating the negative consequences of a slowdown in demand conditions on economic activity and productivity in Canada.

Future research should undertake an empirical analysis of the impact of a slowdown in domestic and external demand on other key productivity drivers: investment in human capital, creative destruction and inter-industry resource shifts. In addition, firm-based research could be undertaken to empirically examine the impact of demand conditions on labour productivity growth in Canada.

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Appendices

Appendix 1: Data Sources

For Canadian industries our dataset consists of 35 two/three-digit NAICS business sector industries for the 1970-2008 period. All data are annual. Both real value added and labour productivity (value added per hour worked) are expressed in chained 2002 Canadian dollars, and obtained from Statistics Canada CANSIM Table 383-0022. The education industry is excluded from our sample due to data unavailability.

Real value-added: Real gross domestic product (GDP) valued at basic prices.

Labour input: The number of hours worked in all jobs, calculated as the product of average annual hours worked per worker and the number of jobs.

Labour productivity: Real GDP per hour worked, constructed by dividing real value-added by labour input.

Capital intensity: The ratio of capital input to hours worked. The growth of capital intensity can hence be calculated as the difference in growth rates of capital input and labour input. Capital input is available in index format with a 2002 base year.

For demand measures related to Canadian manufacturing our dataset consists of expenditure series for the 1981-2011 period. All data are quarterly, seasonally adjusted at annual rates and in chained 2007 Canadian dollars (millions), then converted into annual data. Data on household final consumption, general governments expenditures, gross fixed capital formation in residential construction and export are obtained from Statistics Canada CANSIM Tables 380-0067, 380-0080, 380-0068 and 383-0070, respectively.

Domestic demand: Consists of final household consumption expenditure on goods and services, general government expenditure and gross fixed capital formation in residential construction.

External demand: Total export of goods and services.

For key drivers for Canadian manufacturing labour productivity our dataset consists of 15 three-digit NAICS industries in manufacturing for the 1981-2011 period, with the exception of R&D for 1994-2011.[6] All data are annual and in chained 2002 Canadian dollars (thousands for various investment and millions for R&D, respectively). Data on investment is consistent with CANSIM Table 383-0025 whereas R&D expenditures are obtained from Statistics Canada CANSIM Table 358-0024.

GFC: Capital investment flow consists of information and communication technologies (ICT) machinery and equipment, non-ICT machinery and equipment, building structures and engineering structures.

6 For comparability with R&D data, several three-digit NAICS industries are combined: food, beverage and tobacco [311-312]; textile and textile products [313-314]; apparel and leather product, furniture and miscellaneous manufacturing product [315-316, 337-339]; and paper and printing related product [322-323].

M&E: Machinery and equipment (assets) consist of ICT and non-ICT machinery and equipment.

ICT: Information and communication technologies machinery and equipment consists of computer hardware, software and telecommunication equipment.

R&D: Total business enterprise research and development (R&D) intramural expenditures for work performed within the reporting company, including work financed by others.

OECD data are available through the OECD statistics portal (OECD, 2010). Data coverage varies across countries. The first eight variables are obtained from the National Account Statistics while the last is obtained from the Structural Analysis Statistics, STAN. All data is annual and in 2005 constant U.S. dollars using constant PPPs.

GDP: Gross domestic product (expenditure approach).

Pop: Total population, national account.

LP: Labour productivity as GDP (expenditure approach) per head.

Domestic demand: Consists of final consumption expenditure by households and non-profit institutions serving households (P31S14_S15), final consumption expenditure of general government (P3S13) and gross fixed capital formation in dwellings (P51N1111).

External demand: Exports of goods and services (P6).

GFC: Gross fixed capital formation (GFC, P51) consists of other buildings and structures (P51N1112), transport equipment (P51N1113-1), other machinery and equipment (P51N1113-2), cultivated assets (P51N1114), intangible fixed assets (P51N112) net of dwellings (P51N1111).

Capital intensity: Capital intensity is a ratio of GFC to population for OECD countries.

ME: Machinery and equipment (assets) consist of transport equipment and other machinery and equipment other than that acquired by households for final consumption.

RD: Total research and development (R&D) expenditures of business enterprises.

Appendix 2: Modeling Techniques

A visual stochastic process was used to investigate the time series properties prior to modeling. The Augmented Dickey-Fuller test (Dickey and Fuller, 1979) was applied to each series (in logs) by panel (by Canadian industry or by OECD country). Under the null hypothesis of a unit root we include a constant and trend at levels and a constant only at first difference. Statistical significance of ADF test statistics indicates the existence of unit root and therefore the failure to reject the null. Each series is, however, stationary at first difference as we reject the null. It is evident that all series are integrated of order one.

For the panel unit root test there is no *a priori* assumptions of homogeneity and independence across panels; provided unbalanced panel for OECD countries we apply both Fisher's test by Maddala and Wu (1999) and the Pesaran's (2007) test. These tests confirm what has been established in the individual unit root test within each panel (industry or country).

An important concern with respect to the static Verdoorn Law is whether productivity, output and capital intensity share a common deterministic component. In particular, whether or not they are stationary at levels in some linear combination will determine whether a bivariate vector error correction model (VECM) should be adopted in the presence of cointegration, as opposed to a bivariate vector autoregression (VAR) model. For each industry/country, we follow an Engle-Granger's (1987) cointegration test procedure under the null hypothesis of no cointegration.

We also consider two assumptions under which the first-stage regression is specified; productivity, output and capital intensity share a common deterministic component on one hand, while they share a common deterministic component and trend on the other. Statistical significance of test statistics indicates the existence of unit root and hence leads to a rejection of cointegration.

For panel cointegration test, we follow an error-correction-based procedure developed by Westerlund (2007). The essence is to test for the absence of cointegration by determining whether there exists error correction for individual panel members or for the panel as a whole. Once again we consider two assumptions under the null of no cointegration. In addition, we consider the possibility of a common factor across panels. A sample p-value is bootstrapped by 200 iterations provided cross-panel dependence. The failure to reject the null by panel coincides with the result from the individual cointegration test—modeling the Verdoorn's Law by VAR is then considered.

Furthermore, the Granger causality test proposed by Toda and Yamamoto (1995) confirms the existence of linkages between productivity and output, and yet these linkages are not uniform across panels. In the Canadian business sector, for instance, two-way causality runs in 11 industries, many of which are large in terms of their shares in real value added.

Appendix 3: Technique Notes on Verdoon's Law

Assume a Cobb-Douglas production function such that:

(T1) $Y_{it} = K_{it}^{a}(Ae^{\lambda t}L_{it})^{b}$

where Y, K and L denote output, capital stock and labour input (defined as total population, not employment) respectively, for country I at time t. Technological progress advances at a rate of λ. Parameter a and b are the observed output elasticities of capital and labour respectively; the assumption of increasing returns to scales implies ($a + b > 1$).

Taking logarithms of equation (T1) and rearranging yields:

$$\log(LP_{it}) = \frac{a}{a+b}\log A + \frac{b}{a+b}\lambda t + \frac{a+b-1}{a+b}\log Y_{it} + \frac{a}{a+b}\log(K_{it}/L_{it})$$

where LP_{it} denotes labour productivity for country i at time t. K_{it}/L_{it} denotes per-capita capital. Finally, differentiating with respect to time gives rise to:

(T2) $\dot{LP}_{it} = \frac{b}{a+b}\lambda + \frac{a+b-1}{a+b}\dot{Y}_{it} + \frac{a}{a+b}\dot{k}_{it}$

where $k_{it} = K_{it}/L_{it}$ denotes per-capita capital. The above equation says labour productivity growth can be written as a weighted average of the rate of technological progress, output growth and growth in per-capita capital. Equation (T2) is also known as the capital-augmented dynamic version of Verdoorn's law by Rowthorn (1979). It is likely that per-capita capital is endogenous and so OLS estimation is inappropriate.

Ideally, the growth of per-capita capital should be included in the Verdoorn equation estimation. However, due to the lack of investment data it is typically assumed that output and per-capita capital shares exhibit the same growth rates, i.e. $\Delta log Y_{it} = \Delta log K_{it}/L_{it}$ Equation (T2) thereby collapses to:

(T3) $\dot{LP}_{it} = \frac{b}{a+b}\lambda + \frac{2a+b-1}{a+b}\dot{Y}_{it}$

Equation (T3) is the traditional Verdoorn law first introduced by Kaldor (1966); it describes a linear relationship between labour productivity growth and output growth. The Verdoorn coefficient, $(2a + b - 1)/(a + b)$, should be less than one; in particular, it equals α under the assumption of constant returns to scale.

Let us focus on equation (T2). Rewriting it yields:

(T2a) $\dot{LP}_{it} = \beta_0 + \beta_1\dot{Y}_{it} + \beta_2\dot{k}_{it} + \mu_{it}$

where $\beta_0 = \frac{b}{a+b}\lambda$, $\beta_1 = \frac{a+b-1}{a+b}$, and $\beta_2 = \frac{a}{a+b}$.

We estimate equation (T2a) whose optimal lag order is chosen by means of the Akaike's information criterion (AIC) and the Schwarz's Bayesian information criterion (SBIC). As for all panels the selected optimal lag structure for the dynamic equation is (1, 1), we estimate the following two equations:

(T2b) $\dot{LP}_{it} = \beta_0 + \beta_{11}\,\dot{Y}_{it} + \beta_{12}\,\dot{Y}_{it-1} + \beta_{21}\,\dot{k}_{it} + \beta_{22}\,\dot{k}_{it-1} + \mu_{it}$

There is no reason to assume common returns to scale across all panels; each panel is likely to have its characteristics. That is,

$\beta_{i0} = \beta_0 + u_{i0}$

Accounting for panel-specific effects the reduced form of equation (T2b) can then be written down as:

(T2c) $\dot{LP}_{it} = \beta_0 + u_{i0} + \beta_{11}\,\dot{Y}_{it} + \beta_{12}\,\dot{Y}_{it-1} + \beta_{21}\,\dot{k}_{it} + \beta_{22}\,\dot{k}_{it-1} + \beta_3\,\dot{LP}_{it-1} + \mu_{it}$

To solve the endogeneity problem of equation (4c), we adopt instrumental variables following McCombie and de Ridder (1984) and Millemaci and Ofria (2012). We consider capital intensity as an endogenous variable and we instrument $\dot{k}_{it-1}$ with output growth at time (*t*-2) and (*t*-3), capital intensity growth at time (*t*-2) and time (*t*-3), and labour productivity growth at time (*t*-2). In addition, for the OECD analysis we include logged domestic and external demand as instruments.

A Sectoral Analysis of Ontario's Weak Productivity Growth

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Abstract

Since 2005, labour productivity growth in Ontario's business sector has been zero, greatly under-performing the rest of Canada and being single-handedly responsible for most of what has been described as "Canada's dismal productivity growth." This article examines the issue through detailed sectoral data, and finds a wide range of variation underlying the average productivity growth rate. Some important sectors have maintained decent productivity growth. Other sectors, especially in manufacturing, saw the level of productivity decline significantly. Empirical evidence suggests that weak aggregate demand—due to the high Canadian dollar, the U.S. recession, and global restructuring—was the main cause of weak productivity. Weak demand led to lost economies of scale, particularly due to compositional shifts in the economy.

One of the most widely used economic performance indicators is labour productivity, defined as real GDP per hour worked.[2] Ontario's performance in terms of labour productivity has been very poor over the past several years. This has caused a considerable amount of concern. It is widely noted that, in the long run, increases in real wages and living standards come mainly from productivity growth.[3]

When Canadian economists talk about competitiveness, they almost always bring in the subject of productivity. Many argue that Canada's poor productivity growth has caused international competitiveness to decline. Certainly, our economy appears less competitive than it used to be, based on the evidence of Canada's large trade deficit. If Canadians could be induced to work harder or smarter to boost productivity, it is claimed, competitiveness would improve.

But what if it sometimes works the other way around? What if it is competitiveness that affects productivity growth? That is to say, what if an overvalued exchange rate, by reducing competitiveness and the scale of output, causes lower productivity growth?

This article argues that productivity, when constrained by demand factors, is not an inde-

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2 All references to productivity in this article refer to labour productivity.

3 It should be noted, however, that there is no fixed relationship between productivity and real wage growth. Such a relationship would only exist if the economy was characterized by a simple Cobb-Douglas type production function. Most empirical evidence does not support it. Changes in the relative prices of imports and exports can also play a significant role in raising the standard of living. This is the main reason why Alberta has been doing so well in terms of real income growth.

pendent causal factor that determines standards of living. While there are many reasons for anxiety about the Ontario economy, an excessive focus on low productivity growth, as if it was always a driving factor, is misplaced.

There is both a demand side and a supply side to productivity. From the supply side, there is potential for productivity growth when technology improves, and when workers become more educated and have more and better capital equipment to work with. However, this potential will not be realized if there is insufficient demand. If highly educated individuals are relegated to driving cabs or selling shirts, their investment in education will be wasted. If more output cannot be sold, it will not make sense for companies to invest in more and better equipment to increase output.

Business commentators generally focus on the average productivity growth for the whole economy. If most industries were clustered close to this average, it would be a meaningful indicator. In fact, this average can be misleading, inasmuch as it is the random outcome of a wide range of different sub-components and may therefore not be representative. In order to understand productivity, it is necessary to see what lies beneath, and to look at its performance at the detailed sectoral level. The possibility of doing this has been facilitated by a new experimental database from Statistics Canada that provides detailed sectoral productivity by province.[4] As we peel away the layers, it will be possible to better understand why productivity growth has slowed so sharply in Ontario.

The article consists of seven sections. The first section provides a brief overview of Ontario's productivity performance. The second section illustrates how the composition of output can affect aggregate productivity. The third section examines the effect of export demand on the composition of output, along with implications for productivity. The fourth section looks at service sector productivity. The fifth section presents a three-digit NAICS decomposition of Ontario's productivity growth. The sixth and most important section provides a regression analysis of the relationship between output and productivity growth in manufacturing. The seventh and final section concludes and provides directions for future research.

A Brief Historical Overview

Over the past ten years, Ontario has diverged very sharply from the performance of the rest of Canada (henceforth abbreviated as ROC, which is the total for Canada minus Ontario). Ontario has fallen behind both in labour productivity growth and in a host of other indicators such as employment growth and investment growth. This is due to the fact that Ontario's economy was the most open to international trade in general, and dependent in particular on exports of finished goods and services rather than raw commodities. It was therefore the most susceptible to both the sharp upward valuation of the Canadian dollar that began in 2003, and the deep recession among developed countries (and in particular the United States) that began in 2008.

Ontario had much more to lose than the rest of Canada, starting with a greater dependence on exports. The early 2000s were already weak because of the dot-com recession in the United States. Between 2002 and 2008, Ontario's international exports as a share of GDP fell by nearly 10 percentage points (Chart 1). In contrast, there was hardly any decline in the rest of Canada, where the rising dollar's effect was largely offset by rising international commodity prices. The recession reduced the export/GDP share by an additional 5 percentage points or so, causing

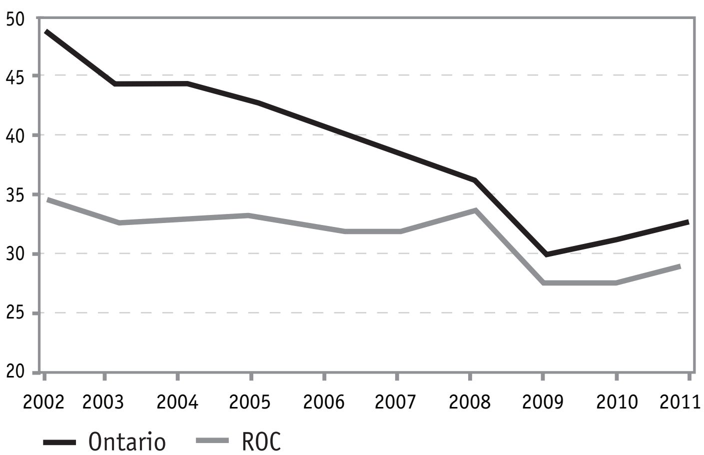
4 The author is indebted to Hugh Finnigan for providing the data, and to Qaizar Hussain and Hugh Finnigan at the Ontario Ministry of Finance for their earlier analysis of the data.

Table 1
Labour Productivity in Ontario and the Rest of Canada
(average growth rates, per cent)

	1984-2000	2000-2005	2005-2011
	Ontario		
Business Sector	1.3	0.8	0.0
Service Sector	1.2	1.6	0.5
Manufacturing	2.6	0.1	0.1
	Rest of Canada (ROC)		
Business Sector	1.2	1.4	0.9
Service Sector	1.2	2.1	1.2
Manufacturing	2.4	1.6	2.0

Source: Statistics Canada, Canadian Productivity Accounts.

Chart 1
International Exports by Ontario and the Rest of Canada
(per cent of nominal GDP)



Source: Statistics Canada, Provincial Economic Accounts.

it to bottom out in 2009. Since then, there has been a modest recovery.

The loss in export sales fed through to weak overall demand and lost jobs. Export industries tend to have higher productivity levels than the average, and the loss of jobs in these industries forced workers to take jobs in much less productive sectors.

Table 1 summarizes labour productivity growth over three time periods for Ontario and the rest of Canada for the business sector, the service sector, and manufacturing.[5]

It can be seen that, prior to 2000, Ontario's performance was quite similar to that of the ROC. Ontario's business sector enjoyed moderate productivity growth, averaging 1.3 per cent per year from 1984 to 2000.

In the six-year period from 2005 to 2011, Ontario's business sector productivity growth was zero (Chart 2). While the ROC showed some weakness related to the recession, it was only modestly lower than its long-run historical average. When people speak about "Canada's abysmal productivity growth," which is a commonly seen phrase in business commentaries, they are talking (whether they know it or not) mainly about Ontario.[6]

Table 1 shows that manufacturing productivity growth was quite a bit stronger than service sector productivity growth in the 1984-2000 period. The service sector increased its share of total business sector output by 6 percentage points over this period. Not only did the service sector have lower productivity growth than manufacturing, but its level of output per hour worked was lower, bringing down the overall average as it increased its share of the economy.[7] This is one example of how the composition of the economy can influence the overall average productivity growth rate.

Similarly, in the 2005-2011 period, overall business sector productivity growth was zero, despite non-zero growth in service sector pro-

5 The comparisons in this article are mainly between Ontario and the ROC. There are serious statistical problems in comparing productivity growth across countries, as noted by Diewert and Yu (2012).

6 Ontario's disproportionate contribution to the national decline has been noted by Sharpe and Thomson (2010), who appear to have coined this widely-quoted phrase. Their analysis covered the period up to 2007, and their conclusions were quite similar to those of this article.

7 As of 2011, real GDP per hour worked in Ontario in the service sector was $35.80 overall, compared to $53.30 in manufacturing. In addition, within services, much of the employment growth has been in sectors where the level of productivity is below the average for services as a whole.

ductivity. In other words, the whole was less than the sum of its parts. This, too, is a function of the changing composition of output, as sectors with below-average levels of productivity increased their share of the total. The next section discussesthe effect of the distribution of output in more detail.

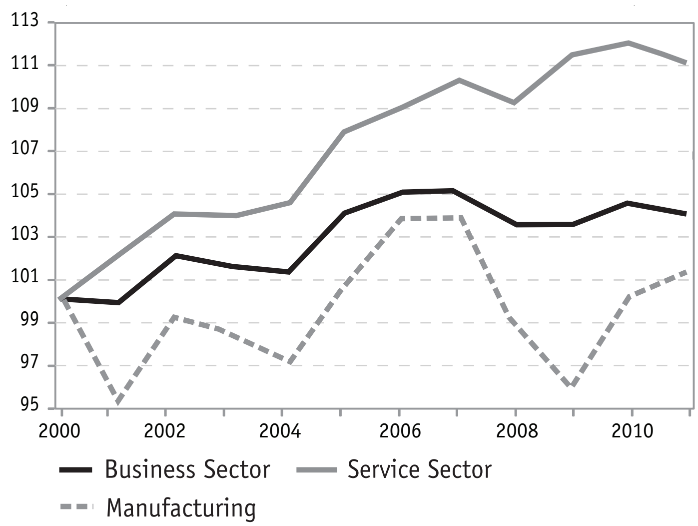
How the Composition of Output Affects Aggregate Productivity

The level of output per hour worked varies greatly across different sectors of the economy. This reflects the earnings of both the physical and human capital of the sector. Some sectors have a high GDP per hour worked, reflecting the high educational levels and incomes of their workers. Other sectors (such as mining and manufacturing) have a high GDP per hour worked because of the high capital-labour ratio, in spite of the relatively low human capital of their employees.[8] In still others, such as food services, there are relatively low levels of both educational requirement (although, anecdotally, many servers have post-secondary education) and physical capital, leading to a low level of value added per hour worked.

Chart 3 shows the variation in labour productivity at the two-digit level of industries. Even at this level, there is a very large range, from GDP per hour worked of $120 in utilities to less than $16 in accommodation and food services. In 2011, Ontario had 446,000 workers in the latter sector, but only 46,000 in the utilities sector.

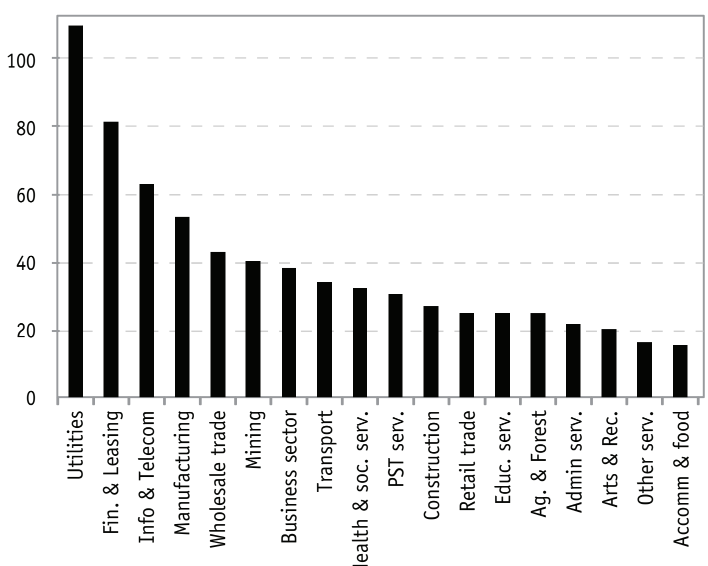
If we drill down further, we find even larger variations. At the three-digit level within the utilities sector, we find pipelines with GDP per hour worked of about $1,000. In the finance and leasing sector, we find an average GDP per hour of $81. However, if we go down to the four-digit

Chart 2
Index of Labour Productivity, Ontario, 2000-2011
(Real GDP per hour worked, 2000=100)



Source: Statistics Canada, Canadian Productivity Accounts.

Chart 3
Labour Productivity in Ontario by Two-digit NAICS Sectors, 2011
(Real GDP per hour worked)



Source: Statistics Canada, Canadian Productivity Accounts.

8 The average wage in manufacturing is only $5 per hour higher than in services, but the output per hour gap is about $17, reflecting the higher capital/labour ratios in manufacturing.

Table 2
A Simple Numerical Example Showing How a Change in the Composition of Output Can Affect Average Measured Productivity

	Hours Worked				Average Productivity in the Economy (Output per Hour Worked)
	Food Services	Manufacturing	Total	Total GDP	
2005	1,000	1,000	2,000	$66,000	$33
2006	1,000	800	1,800	$56,000	$31.1
2007	1,000	600	1,600	$46,000	$28.8

level within that sector, we find a range from $46 in real estate services to $295 in lessors of real estate (the companies that actually own the properties and earn the rent on them). These are very high levels of average productivity, but the marginal productivity from adding additional workers would be much lower than the average productivity. Likewise, the capital itself only has a high productivity if there is a use for it. Pipelines are very expensive, so if the pipeline earns its expected rate of return, the output per hour worked needed to maintain it will be very high. However, there would be no value in building a pipeline if there was no demand for its services, as it would earn a very low rate of return, and the marginal productivity would be far lower than the average productivity of existing pipelines.

In manufacturing, average GDP per hour worked was $53 in 2011, but at the four-digit level we find a range from $22 per hour in agricultural chemicals to $133 in automobile assembly. What is even more peculiar is that several years ago the level for agricultural chemicals was over $80 per hour, and for auto assembly it was over $170 per hour.

Even the four-digit level is highly aggregated, and obscures the considerable differences that can exist between one company and another. Different companies that fall into a category can be vastly different in what they produce and how they do it. Their productivity will fall if they are operating at below capacity because of weak demand, and because they have to keep on managerial and security employees even when the plant is idle.

A Hypothetical Example: Assume an economy that consists of just two sectors, food services and manufacturing. Output per hour worked is $16 in food services, and $50 in manufacturing. As the number of hours worked in manufacturing declines due to lower exports, aggregate productivity (output per hour worked) declines in the economy, as shown in Table 2. In this example, a large decline in aggregate measured productivity occurs, even though there has been no actual change in productivity at the industry level.

The Effect of Export Demand on Output Composition

Ontario's exporting industries, such as auto manufacturing, with output per hour of well over $100, are among the ones that have the highest output per hour. By contrast, local service producing firms and manufacturers that serve the domestic market tend to have lower productivity. The decline in exports has reduced the output of some of the higher-productivity sectors in the Ontario economy. This development would have a negative impact on average labour productivity for the reasons just discussed, even if there was no impact on productivity within any individual industry.

In reality, even productivity at the plant level is often adversely affected, as some of the remaining operations would be operating at a smaller scale, thereby spreading overhead costs over a smaller amount of production.

Many large operations with high absolute levels of GDP per hour worked (such as major steel mills at the former Stelco) were shut down, not being able to compete due to the sudden appreciation of the Canadian dollar. This leaves a larger share of what is classed as manufacturing in less efficient firms that serve local markets, such as small firms processing scrap metal. Other examples include small-scale specialty food manufacturing and custom furniture makers.

It may seem paradoxical that more productive operations fail, while less productive ones remain, but there is considerable segmentation in markets. Some products have a substantial service component (or other characteristics, such as being perishable), and gain an advantage from being closer to markets. Their price elasticity of demand is therefore relatively low, and they can survive despite having lower output per hour worked. Other products which are very generic have to compete in global markets purely on price, and their price elasticity of demand is very high.

The tendency towards smaller-scale operations over the past several years is evident in the data on Ontario employment by class and size of establishment. The employment changes in the Ontario economy over the past several years have been in the direction of smaller scale and lower efficiency.

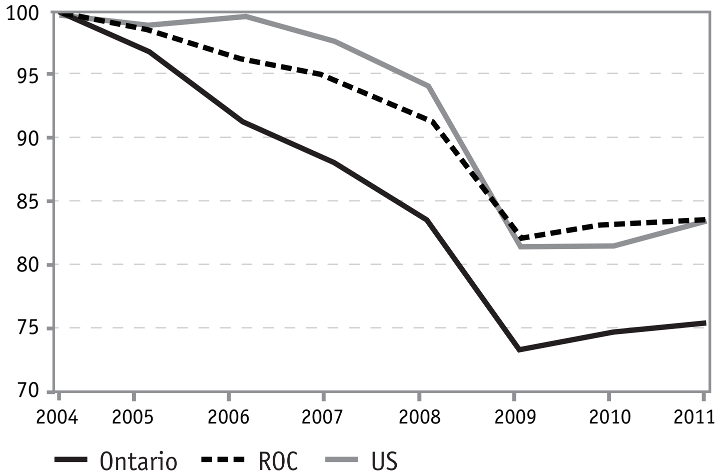
GDP per worker in unincorporated businesses is less than half of the business sector average. If the new participants in that sector since 2007 could instead have been employed at the economy-wide average, that by itself would have boosted real GDP by about half a per cent. That is just the tip of the iceberg, however, as these participants happen to fall into a class of workers for which we have specific data. Overall, there has been a general shift throughout the economy towards firms of smaller size and less efficient scale.

A very detailed study of plant-level productivity by Baldwin and Yan (2010) looked specifically at manufacturing in the period from 2000 to 2006. The authors found that the higher dollar led to a shift away from export orientation, with a resultant weakening of productivity growth: "Export-market participants gain more in productivity growth from currency depreciation than non-participants... the dramatic increase in the value of the Canadian dollar during the post-2000 period almost completely offset the advantages enjoyed by export-market participants. Our counterfactual exercise shows that fluctuations in real exchange rates explain almost all the shifts in productivity growth gaps between export-market participants and non-participants in this latter period."

Between 2003 and 2011, total employment and hours worked in manufacturing in Ontario fell by almost 30 per cent (Chart 4), but the decline was greatest in the firms with the most employees, and hence the firms that would be expected to have the greatest economies of scale. Table 3 shows the share of manufacturing employees by firm size. In Ontario, fewer than 20 per cent of manufacturing workers in 2011 were in firms with more than 500 employees. By comparison, about 50 per cent work for firms of that size in the United States.

The decline in manufacturing productivity growth in Ontario was particularly large, from an average annual growth of 2.6 per cent per year prior to 2000, to near-zero after that. It appears that this can be fully explained by the decline in demand for Ontario's manufacturing output. It is possible to estimate the correlation between manufacturing productivity growth and output growth over the historical period with regression analysis, as described in a later section. As discussed there, the relationship is quite stable, finding nearly identical coefficients

Chart 4
Total Hours Worked in Manufacturing



Source: Statistics Canada, Canadian Productivity Accounts and BEA.

Table 3
Distribution of Manufacturing Employees in Ontario by Firm Size, 2003-2011

	Fewer than 100 Employees	100 to 500	More than 500
2003	40.5	37.2	22.3
2004	40.2	38.6	21.2
2005	41.4	38.2	20.4
2006	42.7	35.5	21.8
2007	42.5	35.7	21.8
2008	44.4	35.6	20.1
2009	49.0	33.8	17.2
2010	47.1	35.0	17.8
2011	46.9	34.5	18.6

Source: Statistics Canada.

in periods of output growth and output decline. This suggests that productivity growth in manufacturing rises about 0.6 per cent with each 1 per cent increase in output growth.

This coefficient is applied in Table 5 to calculate how much higher Ontario's manufacturing productivity growth might have been with higher output matching that of the United States or the ROC.[9] Interestingly, the result is that Ontario would have closely matched productivity growth in those other jurisdictions, which implies that Ontario's weak manufacturing productivity growth is fully explained by its weak output growth. That, in turn, is substantially explained by the high Canadian dollar. The other provinces largely managed to avoid this situation. They export less of their manufactured products, and more of what they produce is of a specialized nature related to their resource industries.

The next section will seek to confirm these macroeconomic estimates by looking at how changes in the micro structure of production contributed to changes at the aggregate level.

Why Has Service Sector Productivity Growth Underperformed?

As seen in Table 1, Ontario also underperformed compared to the rest of Canada in service sector productivity growth, which was positive but weak in Ontario. Table 4 provides the details for the 2005-2011 period.

The most important service sector industry for Ontario is financial services, representing 29 per cent of services output. Ontario's productivity growth slightly outperformed the ROC average for this industry.

The next most important industries are wholesale and retail trade, which together comprise 24 per cent of service sector output. For these industries, Ontario's productivity growth was reasonably good, but substantially lower than the very strong ROC average growth. There does not appear to be much of a difference in trend between Ontario and the rest of Canada in this sector. The relative levels of productivity were not materially different in 2011 than they were ten or fifteen years earlier,

9 Table 5 covers the rates of change from 2005 to 2011, as data on US manufacturing value added for previous years are not available from the Bureau of Economic Analysis.

Table 4
Labour Productivity Growth in Services in Ontario and the Rest of Canada, 2005-2011

NAICS code		% Share of Ontario Services GDP in 2011	2005-2011 (avg. annual growth rates, %) Ontario	Rest of Canada
	Total	100.0	0.5	1.6
410	Wholesale Trade	12.4	1.7	3.1
4A0	Retail Trade	11.7	1.5	2.8
484	Truck Transportation	2.3	-0.9	3.1
485	Transit and Ground Passenger Transportation	1.0	1.0	0.7
486	Pipeline Transportation	0.3	3.7	2.2
48A	Other Transportation	2.8	2.4	2.0
493	Warehousing and Storage	0.3	-2.3	-0.7
49A	Postal Service and Couriers and Messengers	1.2	-1.0	1.3
512	Motion picture and sound recording industries	0.5	x	-0.5*
51B	Publishing, Broadcasting, Telecommunications and Other Information Services	6.9	x	0.0*
541	Professional, Scientific and Technical Services	11.3	-1.3	0.1
561	Administrative and Support Services	4.9	-1.0	0.1
562	Waste Management and Remediation Services	0.7	-0.5	0.5
5A0	Finance, Insurance, Real Estate and Rental and Leasing (excluding owner occupied dwellings)	29.3	1.7	1.3
610	Educational Services	0.5	1.0	-1.3
620	Health Care and Social Assistance	5.4	-0.6	-0.8
710	Arts, Entertainment and Recreation	1.5	-1.3	-1.4
720	Accommodation and Food Services	3.9	1.5	-0.1
811	Repair and Maintenance	1.2	-1.3	1.2
813	Civic and Professional Organizations	0.5	-2.0	-0.4
81A	Personal, Household and Laundry Services	1.5	-1.9	-0.4

X = unavailable due to confidentiality; * denotes value for all of Canada, as ROC cannot be calculated.
Source: Statistics Canada, Canadian Productivity Accounts.

despite the recent stronger growth in the ROC. The differences in the recent growth rates likely reflect the weaker income growth and resulting weaker sales growth in Ontario rather than any fundamental differences. Over the 2005-2011 period, the growth rate of combined nominal retail and wholesale sales in ROC was 27.0 per cent, compared to only 16.4 per cent in Ontario. In addition, one of the activities that people who become self-employed do is small scale, low productivity retailing, and self-employment was the largest area of employment growth in Ontario in this period (Table 5).[10]

There are a number of service sector industries that experienced negative productivity growth. The most significant of these was the professional, scientific and technical services area. In spite of its grand-sounding name, it is a miscellaneous category with over 500,000 jobs that includes low-paying occupations such as bookkeeping services.[11] A surplus of workers willing to take low-paying jobs may have boosted employ-

10 Over the 2005-2011 period, self-employed persons with no employees increased 17.4 per cent in Ontario, compared to only 7.8 per cent in the ROC. Sadly, this was Ontario's only "booming" area of employment.

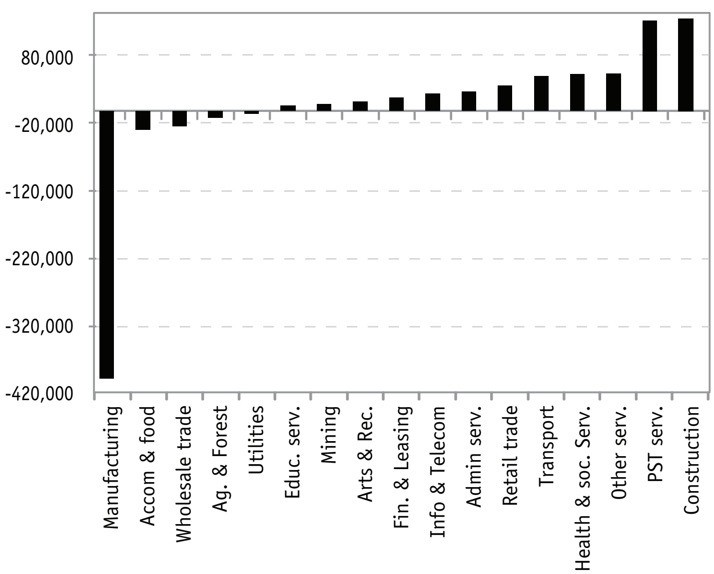
11 About 36 per cent of the workers in professional, scientific and technical services were self-employed in 2011, which is up by about 3 percentage points since 2007 (Cansim Table 282-0011). This is consistent with the view that people who cannot find paid jobs move into fields where they have self-employment opportunities. Especially at first, they often have poor earnings, dragging down the average productivity of the sector.

Table 5
Employment in Ontario by Type, 2007 and 2011

	Thousands of Jobs		Per Cent
	2007	2011	Change
Total business sector employment	5365	5388	0.4
Total employees, firms with 500+ employees	547	472	-13.7
Self-employed with employees	317	309	-2.6
Self-employed without employees	653	719	10.1

Source: Statistics Canada, Labour Force Statistics.

Chart 5
Change in Hours Worked by Two-digit NAICS Sectors in Ontario, 2005-2011
(thousands of hours worked)



Source: Statistics Canada, Canadian Productivity Accounts.

ment in the lower-productivity segments of this classification. As will be discussed in the next section, absolute declines in productivity in particular sectors probably indicate a change in composition. This is often the result of weak demand for the higher productivity activities, which forces people to move into lower productivity ones for the lack of any better alternative.

Three-Digit NAICS Sectoral Decomposition of the Weakness in Ontario's Productivity

This section looks at variations in the economy using the three-digit NAICS code level, which breaks out about 50 business sector industries.[12] The purpose is to estimate the total impact of detailed compositional change and other factors in dragging down aggregate productivity growth in Ontario.

Two types of counterfactual analysis will be undertaken here. The first looks at how productivity would have differed if the growth in hours of employment in all sectors had been the same. This is intended to control for the effect of changes in the composition of the economy. The second analysis will take into account the observation that many of the three-digit sectors had substantial declines in the level of productivity. The reason for these declines is not fully understood, but it probably reflects cyclical drops due to lost economies of scale, excess capacity, and possibly also a shift of composition within the three-digit sector.

The most salient compositional shift is that employment in manufacturing dropped sharply as a share of total employment, and its average productivity is higher than the economy-wide average. Some of the strongest growth areas in employment were in parts of the service sector that have relatively low productivity.

The analysis will be carried out for changes in employment from 2005 to 2011, which was noted in Table 1 as being a period when Ontario's business sector had zero overall productivity growth.

Chart 5 highlights the wide variation in the change of hours worked in Ontario at the two-digit NAICS level. It shows the change in hours worked in terms of absolute numbers, rather

12 In principle, there are 51 categories at the three-digit level of the Productivity Accounts. However, at this level, four of them are suppressed by Statistics Canada for Ontario in order to protect confidentiality, thereby leaving 47 categories for the analysis.

Table 6

Counterfactuals: How Much Would Ontario's Manufacturing Labour Productivity Growth Have Increased if Ontario's Output Growth had Matched that of the Rest of Canada or the United States?

2005-2011	Output, (average annual change, %)	Labour Productivity, (average annual change, %)
Rest of Canada	-0.3	2.2
United States	0.6	3.3
Ontario	-3.4	0.6
If Ontario had matched ROC output growth	add 3.1 to Ontario's output to raise it to -0.3	0.6 + 0.64*3.1=2.6
If Ontario had matched US output growth	add 4.0 to Ontario's output to raise it to 0.6	0.6 + 0.64*4.0=3.2

Table 7

Alternative Scenarios of Ontario Business Sector Productivity Growth, Based on Reversing Adverse Changes at the Three-digit NAICS Level

	GDP in 2011, $billions (2002 constant dollars)	Implied Annual Average % Productivity Growth, 2006 to 2011
Actual business sector GDP in 2011	347.1	0.0
Hypothetical GDP if all sectors had the same per cent change in hours worked from 2006 to 2011 (total hours remaining the same for the whole economy)	359.6	0.6
Hypothetical GDP if no sector had suffered a decline in 2011 relative to its previous maximum absolute level of productivity	371.7	1.1
Combined effect of both of the above adjustments	386.0	1.8

than percentage change, as it is the absolute number that determines its weight in the impact on the overall productivity outcome. For example, mining is a relatively high productivity industry that had a strong per cent increase in hours worked. However, it started from a small base, and a large per cent change represents a relatively small number of jobs and a small amount of GDP. Therefore, it only had a small impact on the overall outcome. There are too many industries at the three-digit level to easily fit into a chart, but the actual analysis will be carried out at the three-digit level. At the three-digit level, the outcome is worsened by the fact that the largest loss in hours in manufacturing was in auto assembly, which is also the sub-sector of manufacturing with the highest level of productivity.

The results of two types of recalculation are depicted in Table 7 above. The first one rebalances the hours worked to calculate the level of GDP that would have existed in 2011 if all sectors had hours growing at the same rate.

The second recalculation makes a more radical alteration. It recognizes that even at the disaggregation provided at the three-digit level,[13] much of the change in composition is hidden. One of the startling features of the sectoral productivity data is that, for a number of industries, the level of productivity in 2011 is well below the peak. The low average productivity growth that occurred was not the

13 The experimental Productivity Accounts also include a four digit NAICS level. This provides a theoretical set of 95 categories, of which 11 are suppressed for Ontario due to confidentiality. This makes analysis at that level problematic, as a larger proportion of the economy is missing.

Table 8

Manufacturing Productivity Levels in Ontario in 2011 Compared to the Peak in the Previous Decade

NAICS code	Name	Level of Productivity in 2011 Relative to Previous Peak (per cent difference)
311	Food Manufacturing	-3.1
312	Beverage and Tobacco Product Manufacturing	-25.4
31A	Textile and Textile Product Mills	-15.1
315	Clothing Manufacturing	-22.1
316	Leather and Allied Product Manufacturing	-4.6
321	Wood Product Manufacturing	-9.1
322	Paper Manufacturing	-6.1
323	Printing and Related Support Activities	-18.2
325	Chemical Manufacturing	-22.1
326	Plastics and Rubber Products Manufacturing	0.0
327	Non-Metallic Mineral Product Manufacturing	-7.0
331	Primary Metal Manufacturing	-12.7
332	Fabricated Metal Products Manufacturing	-8.4
333	Machinery Manufacturing	-0.6
334	Computer and Electronic Product Manufacturing	0.0
335	Electrical Equipment, Appliance and Component Manufacturing	-25.6
336	Transportation Equipment Manufacturing	-9.9
337	Furniture and Related Product Manufacturing	-23.1
339	Miscellaneous Manufacturing	-10.6
3A	Total Manufacturing	-2.2

Souce: Author's calculations, based on Statistics Canada, Canadian Productivity Accounts.

result of all industries growing together at the same weak rate. Rather, it is the average of industries that had positive productivity growth, and others that had large declines not just in growth rate but in level. Industries with substantial absolute declines in productivity are especially prevalent in manufacturing, as seen in Table 8. Out of 19 three-digit NAICS categories in manufacturing, all but two were below their previous peak level of productivity in 2011.[14] In some cases they were far below their peaks, no doubt indicating that some major facilities that had high levels of productivity had been completely shut down.[15]

If weak productivity growth is meaningful as a concept, it must refer to sectors that are not investing enough, or are not innovative enough. These factors would reduce the growth rate, but they would not ordinarily cause a drop in the level far below what had been previously reached.[16] Mere lack of ambition or effort as the causal factors would imply a rate of zero as the floor for productivity growth in each sector. Where sectors are showing large drops, it may

14 It is true that in the process of Schumpeterian 'creative destruction,' certain industries will be undergoing decline even in good economic times. However, 2011 was clearly atypical. Only two out of 19 industries were not below their previous peak, with an average (unweighted) ratio of 0.85 (2011 productivity level divided by the previous peak level). By comparison, in 1999 it was eight out of 19, with an average ratio of 0.92. About half the 19 industries had their peak year of productivity in the 2005-07 period, while the other half peaked as far back as 2000-2003.

15 I have omitted petroleum and coal products (code 324) from the table, pending the verification of a data anomaly. This industry's productivity in 2011 displays a remarkable 66 per cent decline from its peak. There was one major refinery closure in 2005, but this does not appear to be sufficient to explain such a large decline.

be partly because there are unfortunate compositional changes going on within those sectors that we cannot discern from the data. For example, large companies that formerly competed in the export market and had economies of scale have gone out of business, leaving a residue of smaller firms serving the domestic market. The latter survive despite their small scale and inefficiency (from a global perspective) due to the presence of a particular service niche that enables them to operate.

The sectors that are showing absolute declines in the level of productivity account for most of the decline in overall productivity growth. The second recalculation in Table 8 controls for this factor. It shows what the level of GDP in Ontario would have been in 2011 if the sectors for which declining productivity is found in the data had instead stayed at the previous highest level that they had attained before the decline. When both of these calculations are combined, we find that the level would be 11.2 per cent higher than the actual. That is, the zero productivity change actually recorded in the 2006 to 2011 period would instead have been 1.8 per cent per year. This change is higher than the historical average, but not out of the range of variation for a period of six years.[17] What this highlights is that there were some sectors in which companies were making considerable efforts, in the face of adversity, to achieve productivity growth.

The second row in Table 7 reflects the effect of the most obvious form of compositional shift based on the evidence of changes in the relative amount of work done in different sectors. The share of work in sectors with below average productivity has increased, and this accounted for a reduction of 0.6 per cent per year in productivity growth. However, as discussed above, that does not necessarily tell us the whole story about composition. One factor that may explain why certain three-digit NAICS industries had absolute drops in their level of productivity is that a larger share of their output is directed towards local demand (e.g. the customized small-scale operations with a service component, such as cabinet makers, as opposed to large scale furniture manufacturing). These operations tend to be more labour-intensive and have lower productivity. However, the lack of data on productity levels broken down by firm size and by industry means that the importance of this factor is not known.

The Relationship between Output and Productivity Growth in Manufacturing: Regression Analysis

This section uses regression analysis to examine the relationship between output and productivity growth in manufacturing in Ontario. The dependent variable is the year-to-year per cent change in real value added per hour worked, and the explanatory variable is the per cent change in value added. A pooled cross-section regression was run using data for 19 three-digit manufacturing subsectors.

In this type of specification, there is a risk of endogeneity that can bias the results and produce a spurious correlation. Did weak output growth in the post-2000 period cause weak productivity growth? Or was there some exogenous negative shock to Ontario's technology or work attitudes that caused weak productivity growth, which in turn made Ontario companies unable

16 One could think of some extreme examples where productivity would drop due to a lack of investment. For example, this might happen if a company hired more workers without adding more capital, and forced existing workers to share their equipment with new workers. Such behaviour is likely to be rare, particularly in manufacturing, where there has been a large decline in total employment.

17 For example, the average annual productivity growth in the Ontario business sector for the six years ending in 2002 was 2.6 per cent.

Table 9

Regression Estimates for the Effect of Demand Growth on Labour Productivity Growth in Ontario's Three-digit NAICS Manufacturing Sectors

Regression Method	OLS		Instrumental Variables
Sample period (annual data)	1985 to 1999	2000 to 2011	1985 to 2011
Total panel (balanced) observations	300	240	540
Constant	1.1* (1.8)	2.0*** (4.2)	1.6*** (3.4)
Coefficient on change in sector's output growth	0.68*** (10.2)	0.64*** (14.8)	0.45*** (5.0)
Adjusted R-squared	0.26	0.48	0.04
Durbin-Watson stat	2.44	2.25	2.34

t-statistics are in parentheses. *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

to compete, and led to reduced productivity growth?

There are different ways to address this problem, as this is a situation where extrinsic knowledge provides a ready answer. There were two obvious and very large negative demand shocks in the post-2000 period: a more than 60 per cent appreciation in the value of the Canadian dollar, and the worst recession in the industrialized world since the 1930s. In this context, any special factors originating in Ontario that might have independently reduced productivity growth must be very minor by comparison.

In the regressions shown in Table 9, the sample is split into two parts. The first regression covers the period from 1985 to 1999, and the second one from 2000 to 2011. The former corresponds to a period of strong positive output growth, while the latter corresponds mainly to falling output in manufacturing. In spite of the marked difference between the periods, the coefficient on the output variable is almost identical. This gives us considerable confidence that there is a stable structural relationship between productivity growth and output growth. If there was a spurious relationship significantly biased by endogeneity, the very different values of the dependent variable in the two subperiods would likely have resulted in quite different (random) results.

The most rigorous way to deal with this problem is two-stage regression using instrumental variables. This approach was also tried, and it confirms the results. Using just two instrumental variables, a statistically significant coefficient of 0.45 (t=5.0) was obtained, indicating that productivity changes 0.45 per cent for each percentage point change in output.[18] The two instrumental variables were the deviation of the exchange rate from purchasing power parity, and the rate of change in aggregate US manufacturing output. As this is a panel regression with productivity growth in 20 different sectors being used as the dependent variable, the instrumental variable would ideally have consisted of data for those same specific 20 sectors in the United States. Unfortunately, matching data were unavailable. Nevertheless, it is likely that the coefficient in the two-stage regression would have moved upward with better data, and therefore an estimate near 0.6 (used in Table 6) is likely the best one.

At the aggregate level, growth in manufacturing output in Ontario is quite well-explained by both US growth and the deviation of the

18 It will be noticed that the R-squared is very low. As pointed out by Wooldridge (2013: 523), "Unlike in the case of OLS, the R-squared from IV estimation can be negative because SSR for IV can actually be larger than SST. Although it does not really hurt to report the R-squared for IV estimation, it is not very useful, either."

exchange rate from its purchasing power parity value. It can be seen in Chart 6 that the peaks and troughs of the rate of change of Ontario's manufacturing output growth roughly correspond with US real GDP growth, while manufacturing output is far more volatile.

As Chart 7 shows, however, there is a much closer correlation between Ontario manufacturing output and US manufacturing output, which in turn reflects a close integration of the sectors.

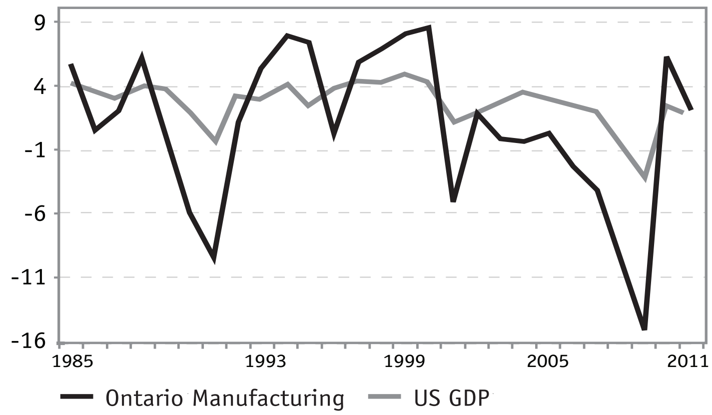
Table 10 reports regression results, where the dependent variable is the annual per cent change in real value added in manufacturing, either in Ontario or the ROC.

The first explanatory variable is the annual percentage change in US manufacturing output. The other explanatory variable is the change from the previous year in the ratio of the actual exchange rate to its PPP value (from the OECD). A rising value implies overvaluation. A distributed lag from t(-1) to (t-4) was found to provide the best fit.

The high coefficient on US manufacturing indicates the high degree of integration of Ontario with the US economy under the Canada-US Free Trade Agreement.

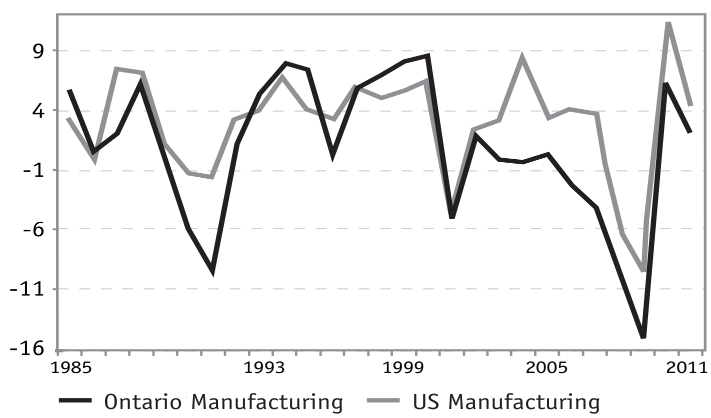
Experiments with alternative distributed lag structures on the exchange rate found that the best fit was obtained by only two lags, t-1 and t-4, which yields the favourable outcome that the adjustment to the exchange rate is completed after four years. If this can be relied on, it would imply that Ontario is over the worst of the adjustment. The effect of the exchange rate on the ***rate of change*** of output has almost completed its adjustment. Note that the dependent variable is the rate of change of manufacturing output. A negative rate of change cumulates to a lower level. This implies a permanent loss in the ***level*** of output as long as the exchange rate remains at its elevated level.[19]

Chart 6
Change in Ontario's Manufacturing Output and US Total Economy Output
(per cent change)



Source: Statistics Canada and BEA.

Chart 7
Change in Manufacturing Output in Ontario and the United States
(per cent change)



Source: Statistics Canada and BEA.

The coefficient on US growth is slightly larger than on the exchange rate, but that does not tell the whole story in terms of the magnitude of impact. The standard deviation of the US growth rate was only 4.5, while the standard

19 A high degree of temporal stability was found. When the regression was estimated over the shorter sample from 1985 to 2001, which leaves out the latest upward trend of the exchange rate, the sum of coefficients was little changed, at -0.73. However, the t-stat was also lower, at -2.6.

Table 10

Regression Estimates Explaining the Growth of Manufacturing Output in Ontario versus the Rest of Canada

	Ontario	Rest of Canada
Sample period (annual data)	1985 to 2011	1985 to 2011
Constant	-1.2* (-1.9)	0.2 (0.3)
Coefficient on annual per cent change in US manufacturing output	0.86*** (6.8)	0.71*** (5.3)
Coefficient on change from the previous year in the ratio of the actual exchange rate to its PPP value (sum over a four period distributed lag)	-0.77*** (-4.8)	-0.28* (-1.6)
Adjusted R-squared	0.82	0.63
Durbin-Watson stat	1.87	1.54

t-statistics are in parentheses. *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

deviation of the exchange rate variable was 6 over the historical sample period. The implication of the distributed lag formulation is that the exchange rate takes about four years to be fully passed through, but the bulk of the impact is felt within three years.

It is interesting to compare the situation of manufacturing between Ontario and the ROC. The coefficient on US growth is almost the same. While the ROC provinces export products related to natural resources, the demand for these products appears to be highly correlated with the US manufacturing cycle.

What is remarkably different is the exchange rate, which is just barely statistically significant in explaining manufacturing output in the ROC, and has a much lower impact. This does not change even when a shorter sample period is used, leaving out the latest upsurge of the exchange rate. The sum of coefficients on the exchange rate distributed lag is -0.77 for Ontario, compared to only -0.28 for the ROC.

These findings probably reflect the greater reliance of the ROC on exports of natural resource commodities, whose prices are set internationally in US dollars, and which tend to be correlated with the exchange rate. Much of what is classed as manufacturing in those provinces consists of either processing those commodities, or providing inputs into the commodity production. Strong commodity prices encourage natural resource production in those provinces, as well as resource-related manufacturing activities.

Conclusions and Directions for Further Research

The analysis in this article has found that the productivity behaviour of the sub-sectors of the Ontario economy is very diverse. There is not a single low rate of labour productivity growth that is found uniformly throughout the Ontario economy, like a pervasive miasma of mediocrity.

The aggregate productivity growth rate for Ontario's business sector averaged zero over the past six years, but this does not mean that all industries experienced zero productivity growth. A few had quite strong growth, while others suffered absolute declines in their productivity level.

By and large, it is possible to explain the overall weak productivity with reference to weak demand growth. Weak demand for Ontario's production has resulted in various adverse effects on productivity. It has led to lower capacity utilization, and to overhead expenses being spread over a smaller base. It has also led to people who have lost jobs in higher productivity sectors to shift into whatever jobs they could get, and these jobs are often at lower productivity levels. Additionaly, many of the higher productivity sectors in Ontario were dependent on exports, and exports were very hard hit by external shocks.

The situation was particularly acute in manufacturing, where 18 out of 20 sub-sectors ended up at a lower level than their previous peak, in some cases much lower. It is ironic that many analysts call for increased productivity as a way to increase Ontario's competitiveness. However, the causality tends to run the other way. It is the lack of competitiveness of some major facilities (due to an overvalued exchange rate) that previously had high productivity levels (as measured by GDP per hour worked) that caused them to be shut down, and reduced the average level of productivity in the economy.

If weak productivity growth is the result of weak exports growth, then there is nothing that the provincial government can do to remedy the situation. On the plus side, it is likely that the worst is behind us and there will be a gradual improvement in the coming years. Indeed, exports have bottomed out and have already turned up as a share of GDP. There is some hope for stronger growth in the United States in the coming years, boosting exports further. Yet, it is hard to predict what will happen to the Canadian dollar. While a high dollar will likely continue, the economy will gradually adjust to this reality, partly through downward adjustments to wage rates that can eventually (albeit slowly and painfully) restore competitiveness.

It is important to ensure that the current obstacles to exporting from Ontario are minimized, and if possible reversed. Hence, the Ontario government should continue to try to influence the federal government's position on the exchange rate and on international trade treaties. For example, it is possible that some tax levers could be used to provide greater benefits to exporting industries.[20] Furthermore, it is likely that infrastructure and border issues have had a negative impact on Ontario's exports over the past several years. Some remedial action has been taken on that, but some aspects of it (such as the new bridge and road infrastructure at Windsor) will not be completed for many years.

Further research is needed to understand why Ontario's exports and manufacturing production suffered so much more than those of the ROC or the United States. The exchange rate and the heavy reliance on the auto sector is no doubt the largest part of the story, but without further analysis, we cannot be certain that it explains all of it. It is important to understand what might be different in terms of structure and the regulatory environment in Ontario as compared to the rest of North America that might have worsened Ontario's performance. Given the ongoing risks of adverse demand shocks, it is important to have a workforce that is as flexible as possible, to allow rapid movement out of declining sectors into growing ones. If it is found that Ontario has its own peculiar adverse institutional factors, it may be possible to fix those and achieve a more favourable outcome.

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20 The prevailing philosophy in taxation is a "level playing field" view that does not favour one sector over another. However, this approach is not supported by economic theory, which implies that lower tax rates should apply to sectors that face a higher price elasticity of demand.

Multifactor Productivity Growth Estimation in Canada and the United States: Do Different Methodologies Matter?

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Abstract

National statistics offices in different countries, as well as individual researchers, make a range of different assumptions and use different approaches to estimating multifactor productivity (MFP) growth. As a result, MFP growth estimates can vary for methodological reasons across countries and for a particular country over a given time period. These methodological choices typically reflect a combination of data availability and the objectives of the study. In this article, we use "reasonably" comparable data for output, labour and capital in Canada and the United States to investigate the sensitivity of MFP growth estimates (by industry and for the business sector in the two countries) to three alternative methodological assumptions. We show that MFP growth estimates for both countries and the Canada-U.S. MFP growth gap are fairly robust to the alternative methodologies and assumptions considered.

National statistics offices in different countries, as well as individual researchers, make a range of different assumptions and use different approaches to estimating multifactor productivity (MFP) growth. As a result, MFP growth estimates can vary for methodological reasons both across countries and for a particular country, over a given time period. These methodological choices typically reflect a combination of data availability and the objectives of the study. National statistical offices, for example, typically have access to more disaggregated data than outside researchers, whose data access is constrained by confidentiality considerations. Other differences reflect different theoretical and practical considerations related to, for example, calculations of the user cost of capital, which can have implications for the measurement of capital input growth and therefore MFP growth. In this article, we use "reasonably" comparable data for output, labour and capital in Canada and the United

1 We would like to thank Wulong Gu for excellent support of our data development at Statistics Canada. We are also grateful to him, Andrew Sharpe and two anonymous referees for helpful comments and suggestions. The views and opinions expressed in the report are the authors' and do not represent those of Industry Canada or of the Government of Canada. Jianmin Tang is Chief, Productivity and Trade, and Larry Shute is Acting Director General in the Economic Research and Policy Analysis Branch of Industry Canada. Jiang Li worked at Industry Canada for this project, and is currently a PhD candidate at the University of Victoria. Emails: jianmin.tang@ic.gc.ca; larry.shute@ic.gc.ca; berylli@uvic.ca.

States to investigate the sensitivity of MFP growth estimates (by industry and for the business sector in two countries) to three alternative methodological assumptions. We show that MFP growth estimates for both countries, and the Canada-U.S. MFP growth gap, are fairly robust to the alternative methodologies and assumptions considered.

Productivity measures how efficiently inputs are translated into outputs. It is often defined as output per unit of input. Productivity growth is the single most important driver of an economy's health over the longer-term. It is the key determinant of economic growth, improvements in living standards, quality of life, and competitiveness. Productivity gains are also important for workers, consumers, businesses and governments because they translate into real wage gains, lower prices, higher profits, and increased tax revenue. Productivity growth will become increasingly important to Canadians in the future due to the ageing of the population; slower labour force growth; and increased competition from emerging economies such as China and India.

The term "productivity" is commonly used to refer to labour productivity, which is defined as output per hour worked. However, labour productivity is only a partial measure of production efficiency. A better indicator is multifactor productivity (MFP), also called total factor productivity (TFP). MFP measures how efficiently all inputs are used in the production process.

MFP growth, or the Solow residual, is calculated as growth in real output minus the weighted sum of growth in labour and capital:

(1) $\Delta lnMFP_t = \Delta lnY_t - (\bar{v}_{L,t}\Delta lnL_t + \bar{v}_{K,t}\Delta lnK_t)$

where Y_t is real value added; L_t and K_t are labour and capital inputs; and $\bar{v}_{L,t}$ and $\bar{v}_{K,t}$ are the two-period average labour and capital income shares of value added.

MFP estimates typically take into account changes in the quality of the inputs, due to shifts in their composition. For example, labour input measures are adjusted to reflect the gender, age and education levels of workers. As a result, the quality changes are excluded from the MFP measure. Thus, MFP is primarily influenced by business innovation; management practices; allocation of productive resources; and economies of scale and scope. Unlike capital and labour, these factors are difficult to quantify and isolate in practice, and thus are reflected in the residual. This is true at the level of plant, firm, industry or country. In addition, mis-measurements of either labour or capital will also be included in MFP, the residual.

Labour productivity is more popular and commonly used than MFP because it is more closely related to GDP per capita and easier to measure, interpret, and update. Compared to labour productivity, MFP is much harder to measure and difficult to keep up-to-date. For instance, it is much easier to measure the number of hours worked than to estimate labour services that are adjusted for the composition of workforce.

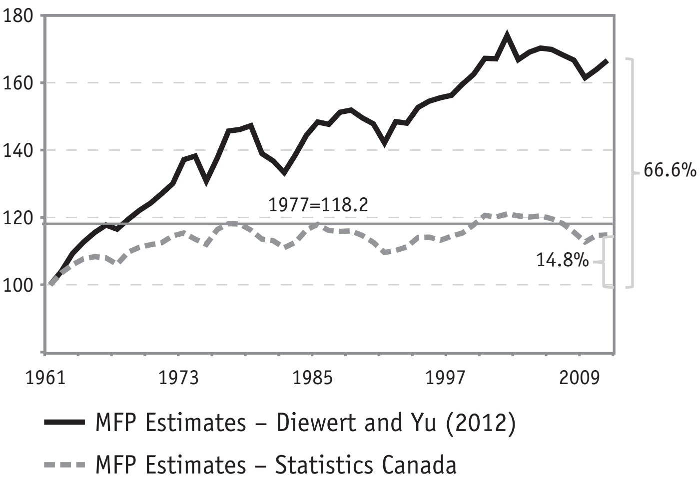
In this article, we investigate if alternative methodological assumptions matter for MFP growth estimates in Canada, and if so, how they affect the estimates in the United States relative to those in Canada. In particular, we go to great lengths to develop the necessary datasets for three alternative methodologies, using the same raw data. Under those alternative methodologies, we then estimate and compare MFP growth by industry and for the business sector for both Canada and the United States.

The remainder of the article is organized as follows. The motivation section highlights the difficulty in measuring MFP. The methodology section lays out the alternative assumptions and methodologies for checking the sensitivity of MFP estimates in the article. The data section, which is followed by a discussion of the results, describes data development for the alternative MFP methodologies. The last section concludes.

Chart 1

MFP Growth in the Canadian Business Sector, Comparison between Diewert and Yu and Statistics Canada, 1961-2011

(1961=100)

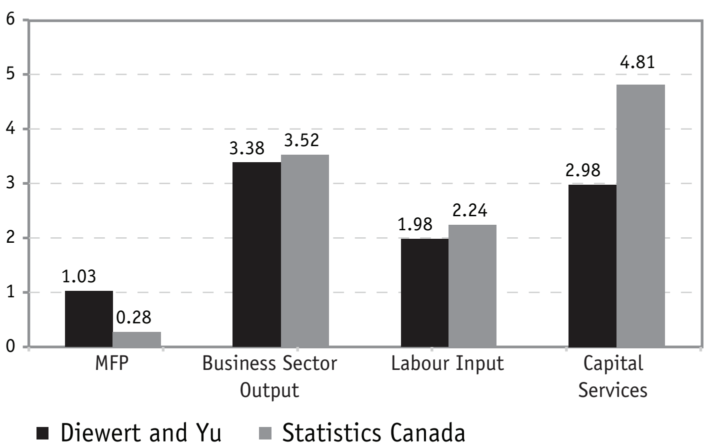


Source: Diewert and Yu (2012).

Chart 2

MFP, Output and Input Growth in the Canadian Business Sector, 1961-2011

(compound annual growth rate, per cent)



Source: Diewert and Yu (2012).

Motivation

The difficulty of measuring MFP is highlighted by Tang, Rao, and Li (2010) and the symposium on the measurement of MFP in Canada in the 2012 Fall issue of the *International Productivity Monitor* (IPM). Tang *et al*. show that official capital and MFP estimates are not completely comparable across countries due to official statistics agencies in different countries using substantially different asset depreciation rates in estimating capital stock.[2]

The IPM Symposium demonstrates that MFP estimates may also be sensitive to the choice of methodologies and the assumptions made in calculating MFP. In estimating MFP growth in the Canadian business sector, one needs first to estimate output and inputs (capital and labour) at the aggregate level. Statistics Canada's Canadian Productivity Program (CPP) assumes different real returns across capital assets and follows a bottom-up approach to aggregate each input from industry level. In contrast, Diewert and Yu (2012) assume the same real return to different capital assets and follow the top-down approach by ignoring the industry dimension. As a result, MFP growth in the Canadian business sector over the 1961-2011 period is estimated to have been 1.03 per cent per year by Diewert and Yu and 0.28 per cent per year by the CPP (Chart 1).

More specifically, the difference between the two MFP estimates is largely due to the difference in estimates of capital service inputs (Chart 2). Growth in capital service by the CPP is on average higher than that in Diewert-Yu by 1.8 percentage points per year from 1961-2011.

Capital service inputs are the sum of different capital stocks, weighted by their user costs. For each asset, user costs equal the nominal rate of

2 Capital services are the weighted sum of different types of capital stocks, with weights being the capital income shares of those capital stocks. The capital stock of asset a for industry j at year t is commonly estimated using the perpetual inventory method, $K^a_{jt} = K^a_{j,t-1}(l - \delta a) + I^a_{jt}$, where I^a_{jt} is the real dollar investment in asset a of industry j at year t, and δ_a is the depreciation rate for asset a. The perpetual inventory method of estimating the capital stock suggests that capital stock and thus capital services are sensitive to the choice of asset depreciation rates, especially in level terms.

return to the asset minus its price change, plus the depreciation rate and the rate of taxation on the asset. The nominal rate of return to the asset minus the price change for the asset in the equation is referred to as the real rate of return to the asset. The depreciation rate and the rate of taxation are pre-determined. Both Statistics Canada and Diewert and Yu calculate rates of return endogenously. That is, the sum of the user costs across all capital equals total capital compensation (i.e. nominal output minus labour compensation).

Gu (2012) shows that the difference in the estimates of capital service inputs between the CPP and Diewert and Yu is mainly attributable to methodologies and assumptions made in estimating capital service inputs (Table 1). He demonstrates that three factors—bottom-up versus top-down approach, equal nominal versus equal real rates of return across assets, and 28 versus 14 reproducible assets—account for more than 90 per cent of the difference in growth in capital service inputs. To a large extent, the difference in these three factors ultimately boils down to the difference in the estimates of real rate of return, in addition to the fact that underlying data used by the CPP and Diewert-Yu are different in many aspects.[3]

Following the bottom-up approach, the CPP first estimates capital service inputs, together with output and labour inputs, by industry (about 90 industries in total), and then aggregates over industries to obtain business sector totals. This approach captures any variation in the rates of return across industries even for the same type of asset. Gu (2012) argues that the methodology employed by the CPP is also used by many countries, which improves the comparability of Statistics Canada's MFP estimates with those of others, particularly the United States. In contrast, Diewert and Yu estimate capital service inputs only at business sector level, and implicitly assume that rates of return do not vary across industries.

Table 1
Sources of Differences in Capital Services Input Growth between Diewert and Yu and the Canadian Productivity Program
(compound annual growth rate, per cent)

	1961-2011	1961-1980	1980-2011
CAP minus Diewert and Yu (2012)	1.8	2.4	1.5
Accounted by:			
Bottom-up vs. top-down approach	0.8	1.2	0.6
Variable land vs. constant land	0.0	-0.1	0.1
Equal nominal vs. equal real rates of return across assets	0.5	0.7	0.3
28 vs. 14 reproducible assets	0.4	0.8	0.1
Unexplained	0.2	-0.2	0.4

Source: Gu (2012).

The second main difference relates to the assumptions made in calculating the real rate of return to asset, defined as the nominal rate of return minus the rate of price change in asset. For each industry, the CPP calculates the real rate of return, assuming that the nominal rate of return for an asset is equal for all assets within an industry, and that the rate of price change in the asset can be approximated by the actual price change in investment. In contrast, Diewert and Yu believe that the actual price change in investment is too volatile to be a proxy for the rate of price change in asset. They calculate the real rate of return, assuming that it is equal for all assets and for all industries (implicitly, since the industry dimension is ignored).

Thus, the difference in methodology in estimating capital service inputs between the CPP

3 For instance, investment in physical capital is benchmarked to the input-output tables in the CPP estimates, but not in the Diewert and Yu estimates. In addition, asset depreciation rates are assumed to be constant in the CPP, but are variable under Diewert and Yu. Finally, the land volume estimate for the CPP equals the dependable agriculture land for cultivation and urban land while it is assumed to be constant under Diewert-Yu.

and Diewert and Yu boils down to their different ways in estimating the rate of return to capital. The former methodology allows for flexibility in the real rate of return, specific to asset and to industry, while the latter does not. Gu (2012) argues that growth in capital services by the CPP is higher because their approach controls for the shifts in composition of capital input. In particular, in addition to giving more weight to rapidly depreciation assets such as high-tech equipment (including computers, software and communications equipment) as in Diewert and Yu, the CPP also gives more weight to those assets due to the substantial decline in their prices. As investment in high-tech equipment has become increasingly important over time, capital service estimates by the CPP have thus grown faster than those by Diewert and Yu.

The debate highlights the methodological and measurement issues in estimating MFP. Unlike labour productivity, MFP estimates require that researchers and government statistical analysts adopt a methodology to develop capital service estimates. Alternative methodologies used to estimate capital service embody different assumptions for which there is no international standard. National statistical agencies employ different, complex methodologies; even those who employ similar methodologies may choose among alternative assumptions, which vary with judgments about, among other things, the quality of the underlying data and the preferred approach by agencies. Therefore, MFP estimates may vary.

Alternative MFP Methodologies

For the design of alternative methodologies at the industry and business sector levels, we follow closely the two alternative methodologies that are used by the CPP and by Diewert and Yu (2012). In addition, for Canada-U.S. comparisons, we also consider both Statistics Canada and BEA asset depreciation rates, as Tang *et al.* (2010) show that the choice of the depreciation rate may affect MFP estimates. Thus, at the industry level, the methodologies differ in the choice of asset depreciation rates and the assumption on the return to capital (Figure 1). For the business sector, they also differ in aggregation approach - top-down versus bottom-up.

The Industry Level

At the industry level, we have four scenarios:

Ind1 Using *Statistics Canada asset depreciation rates* and assuming the *nominal* rates of return to capital are the same across asset types at the industry level

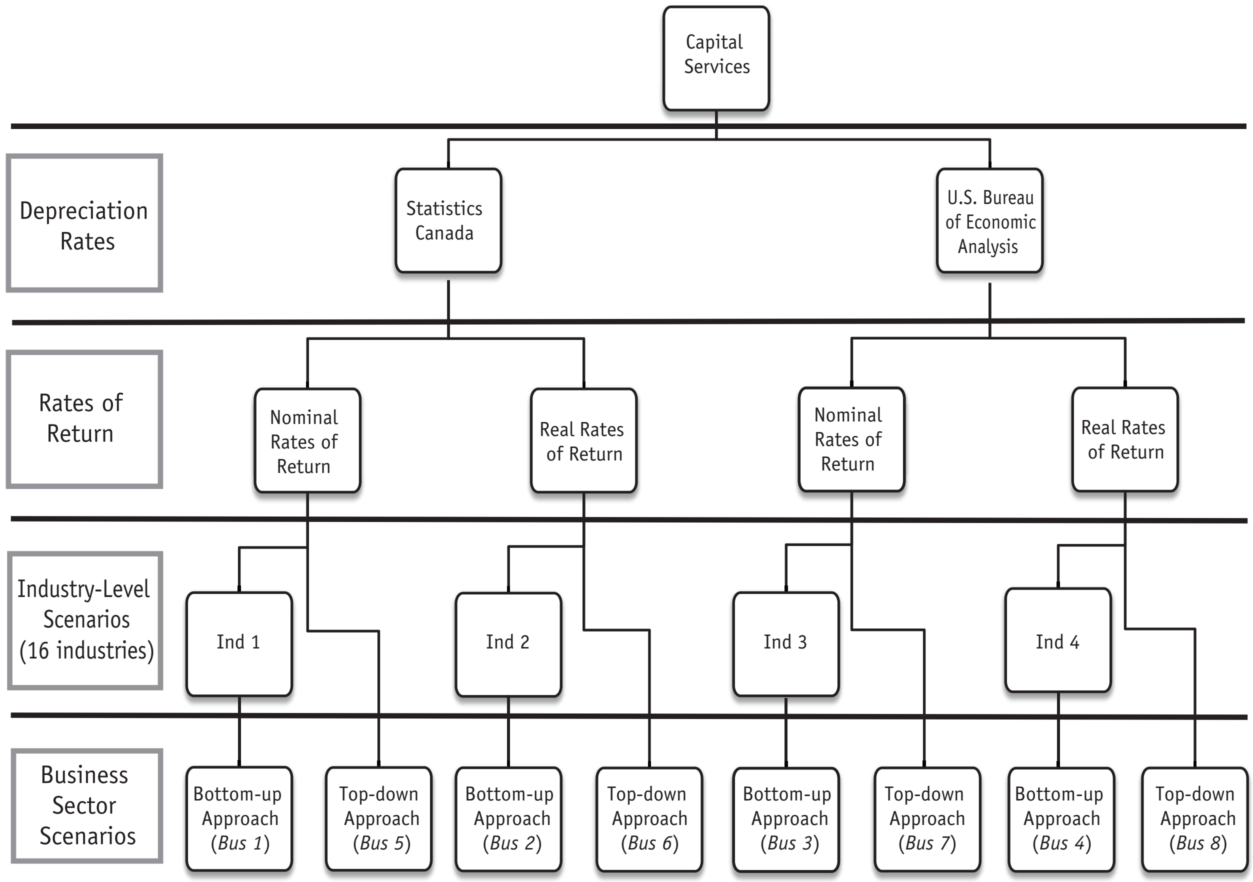
Ind2 Using *Statistics Canada asset depreciation rates* and assuming the *real* rates of return to capital are the same across asset types at the industry level

Ind3 Using *BEA asset depreciation rates* and assuming the *nominal* rates of return to capital are the same across asset types at the industry level

Ind4 Using *BEA asset depreciation rates* and assuming the *real* rates of return to capital are the same across asset types at the industry level

Since output and labour input are the same, differences in MFP estimates in these four scenarios depend entirely on how capital services are calculated. The use of Statistics Canada asset depreciation rates in general leads to lower levels of capital stocks and higher rates of return to capital, compared to the use of BEA asset depreciation rates. The assumptions of the nominal and real rates of return to capital being the same across asset types, which are used respectively by the CPP and by Diewert and Yu, represent two "extremes". The former will generate the most volatile rates across different asset types, while the latter, by definition, will produce the same rate of return to capital for all assets.[4]

Figure 1
Alternative Capital Services Scenarios at the Industry and Business Sector Levels



The Business Sector

At the business sector level, each variable (GDP, labour services, or capital services) can also be constructed by either the bottom-up or the top-down approaches. As discussed earlier, using the bottom-up approach, each variable is aggregated over the same variable across industries. In contrast, using the top-down approach, the industry dimension is ignored and each variable is constructed directly at the aggregate level. Consequently, we end up with 8 scenarios, indicated by Bus1, Bus2, ..., and Bus8.

Bus1 Bottom-up from Ind1
Bus2 Bottom-up from Ind2
Bus3 Bottom-up from Ind3
Bus4 Bottom-up from Ind4

The first four scenarios for the business sector, Bus1-Bus4, are bottom-up-approach based. In other words, for these scenarios, each variable is aggregated over industries, corresponding to Ind1-Ind4. By design, the

4 Under the assumption of the nominal rate of return to capital being the same across all asset types, the rates of return to capital by industry for both Canada and the United States are found to be positive, albeit volatile. To study the impact of volatility on capital services estimates, we make no attempt to replace "outliers" by some external rate of return or by some industry average. The main purpose of calculating the rate of return to capital here is to allocate total capital compensation among different types of capital stock. The rate of return to capital is influenced by other factors, in addition to asset depreciation rates and the assumption of an equal nominal/real rate of return to capital. For example, the rate of return will be lower when other types of capital such as land and inventory are included.

Table 2

Industry Classification and Industry Share of Nominal Value Added and Hours Worked, 2010

No.	Industry	NAICS Codes	Nominal Value Added (per cent) Canada	Nominal Value Added (per cent) United States	Hours worked (per cent) Canada	Hours worked (per cent) United States
1	Agriculture, forestry, fishing, and hunting	11	2.0	1.5	2.7	2.9
2	Mining and oil and gas extraction	21	10.7	1.9	1.7	0.7
2.1	Oil and gas extraction	211	7.9	1.1	0.5	0.2
2.2	Mining	212 & 213	2.7	0.8	1.2	0.6
3	Utilities	22	2.8	1.9	0.8	0.5
4	Construction	23	8.0	4.7	9.3	6.8
5	Manufacturing	321-339	12.9	15.3	11.2	11.4
5.1	Wood products	321	0.6	0.2	0.6	0.3
5.2	Non-metallic mineral products	327	0.4	0.3	0.4	0.4
5.3	Primary metals	331	1.0	0.4	0.5	0.4
5.4	Fabricated metal products	332	1.1	1.1	1.2	1.3
5.5	Machinery	333	1.0	1.3	0.9	1.0
5.6	Computer and electronic products	334	0.5	2.4	0.5	1.1
5.7	Electrical equipment	335	0.3	0.4	0.3	0.3
5.8	Transportation equipment	336	1.4	1.1	1.2	1.3
5.9	Furniture and miscellaneous manufacturing	337 & 339	0.7	1.1	1.0	0.9
5.1	Food, beverage, and tobacco products	311 & 312	2.3	1.6	1.8	1.6
5.11	Textile mills and textile product mills	313 & 314	0.1	0.1	0.1	0.2
5.12	Apparel and leather and allied products	315 & 316	0.1	0.1	0.3	0.1
5.13	Paper products and printing	322 & 323	1.1	0.8	1.0	0.9
5.14	Petroleum and coal products	324	0.5	1.6	0.2	0.1
5.15	Chemical products	325	1.0	2.1	0.7	0.8
5.16	Plastics and rubber products	326	0.6	0.6	0.7	0.6
6	Wholesale trade	41 or 42	6.1	5.9	5.7	5.2
7	Retail trade	44-45	6.7	6.7	11.3	11.7
8	Transportation and warehousing	48-49	5.1	3.5	5.6	4.1
9	Information	51	4.1	5.5	2.6	2.5
10	FIRE* and management of companies	52-53, 55	12.6	19.8	7.2	8.9
11	Professional, scientific, and technical services	54	5.8	10.1	6.9	7.5
12	Administrative and waste management	56	2.9	3.9	5.0	6.9
13	Education, health and social assistance	61-62	13.7	11.6	15.8	16.6
14	Arts, entertainment, and recreation	71	1.1	1.2	2.0	1.5
15	Accommodation and food services	72	2.5	3.4	6.2	7.3
16	Other services (except public admin)	81	3.0	3.2	6.0	5.6
Business sector		11-81	100	100	100	100

* FIRE stands for Finance, Insurance, Real Estate, Rental and Leasing.

Source: Statistics Canada, the U.S. Bureau of Economic Analysis (BEA) and the U.S. Bureau of Labor Statistics (BLS).

only difference among these four scenarios is in capital services.

The remaining four scenarios, Bus5-Bus8, are top-down-approach based; that is, each variable is constructed at the aggregate level with no industry dimension being considered. Output and labour services do not vary across scenarios. Real output is aggregated over final demand categories, and labour input is the sum of hours worked by different types of labour, weighed by their labour compensation shares. Capital services, based upon different assumptions, are aggregated over different asset types at the business sector level. They vary across scenarios:

Bus5 Top-down, using *Statistics Canada asset depreciation rates* and assuming the *nominal* rates of return to capital are the same across asset types

Bus6 Top-down, using *Statistics Canada asset depreciation rates* and assuming the *real* rates of return to capital are the same across asset types

Bus7 Top-down, using *BEA asset depreciation rates* and assuming the *nominal* rates of return to capital are the same across asset types

Bus8 Top-down, using *BEA asset depreciation rates* and assuming the *real* rates of return to capital are the same across asset types

Scenario Bus 1 is the method adopted by the CPP, while scenario Bus 6 is the one employed by Diewert and Yu. The MFP growth estimates are, in general, different between the bottom-up and the top-down approaches. The top-down MFP represents the production possibility frontier (Jorgenson *et al.* 1987), assuming fully efficient input markets.[5] Compared to the bottom-up MFP, which is a weighted aggregate over industries with industry-specific input prices, the top-down MFP also captures the effects of the reallocation of capital and labour inputs among industries (Jorgenson, 2012). If the reallocation effects are positive, then the top-down MFP will exceed the bottom-up one. This would be the case if industries with more rapid growth in inputs also paid relatively high per-unit prices for these inputs.

The positive reallocation effect does not necessarily indicate an inefficient allocation of production resources. For example, a positive reallocation effect associated with capital may very well capture industry dynamics: some industries are growing faster and are more profitable than others. This is because for all these alternative methodologies, capital compensation is the residual of nominal output minus labour compensation, and the rate of return to capital is endogenously determined. The positive reallocation effect reflects the process of resources being allocated to growing and more profitable industries.

Data Development

For our analysis, we develop comparable data for both Canada and the United States for each scenario listed in the previous section. We start with industry grouping. For this study, the business sector is classified into 16 broad industry groups which are at single or combined two-digit NAICS level (Table 2). For the mining and manufacturing sectors, we further divide them, respectively, into 2 and 16 industries at single or combined three-digit NAICS level. The classification is mainly driven by complying with Statistics Canada confidentiality constraints.

In Table 2, we report for both Canada and the United States value added and hours worked shares of each industry in the business sector as an indicator of its relative importance in the two economies. Relative to the United States, the Canadian business sector has higher employment and output shares in resource industries (such as mining, especially oil and gas extraction; wood products; primary metals; and food, beverage and tobacco products), construction, and transportation and warehousing. On the other hand, it has lower shares in computer and electronic products; chemicals; FIRE (finance, insurance and real estate, rental and leasing); and management of companies, and professional, scientific and technical services.

5 In other words, input prices are the same across industries.

In this article, all Canadian industries include private and non-private activities (if applicable).[6] The "business sector" is total economy minus public administration and owner-occupied dwelling. Thus, our aggregate "business sector" differs from the standard business sector that includes private activities only. Despite this departure, for simplicity, we continue to refer to the aggregate as the business sector in this article.[7]

Value Added

Data on industry value added in Canada are a special tabulation from Statistics Canada, consistent with CANSIM Table 379-0023 for value added in nominal dollars and Table 383-0021 for real value added. To ensure comparability with capital data, which is discussed below, the value added data are adjusted to include both private and non-private activities (excluding government services). However, they exclude imputed rental income for owner-occupied housing. Moreover, to make it comparable to the U.S. data, the original value added data at the basic prices are adjusted to value added at factor costs, using information on net indirect taxes on production from input-output tables from Statistics Canada.

The U.S. data on industry value added are from the U.S. Bureau of Economic Analysis (BEA). To make them comparable to Canadian data, two adjustments are made. First, the rental imputation for owner-occupied housing is excluded from real estate. Second, value added at market prices is adjusted to value added at factor costs, using information on net indirect taxes on both products and production that are also from BEA.

For the business sector, nominal GDP is the sum of industry nominal value added. Real GDP based on the bottom-up approach is aggregated over real value added at the industry level, using a Tornqvist index. Real GDP based on the top-down approach is derived from nominal GDP deflated by the top-down implicit GDP price deflator for the business sector. For Canada, the implicit GDP deflator for the business sector is from Statistics Canada. Similarly, the implicit price deflator for the U.S. business sector is from the U.S. Bureau of Economic Analysis. Both are constructed based on final demand categories.

Labour Input

Labour input is an index, obtained by aggregating different types of labour using labour compensation as weights. It equals the product of hours worked and labour quality. To be consistent with output and other inputs, hours worked data for both Canada and the United States are hours worked for all jobs, including both private and non-private activities. The hours worked data for Canada are a special tabulation, consistent with CANSIM table 383-0009. For the United States, they are from the Bureau of Labor Statistics (BLS), consistent with its prototype BEA/BLS Industry-level Production Account (Fleck *et al.*, 2012). To derive labour services estimates, the hours worked data are supplemented by data on labour quality constructed from detailed labour matrixes. The labour matrix by industry has three dimensions: gender (male and female), skill (low-, medium-, and high-skilled), and age (15-29, 30-49, and 50+).[8] For

6 For instance, the public portion of water treatment is included in utilities, while public education and health are in education, health and social assistance. Note, however, that this article excludes owner-occupied dwellings from FIRE and management of companies.

7 For each of the listed scenarios, our database contains data on output (nominal and real); labour (hours worked, labour services, and labour compensation); and capital (capital services and capital compensation for ICT, non-ICT M&E, and structures).

8 Skill is based on education: high school graduate or less (low-skilled); post-secondary education or some university education (medium-skilled); and bachelors or higher (high-skilled).

Table 3
Bureau of Economic Analysis and Statistics Canada (Productivity Accounts) Depreciation Rates by Asset Type

Asset Code	StatCan Asset Classification	Depreciation Rate Implicit BEA	Depreciation Rate Statistics Canada	Asset Class
1	Office furniture, furnishing (e.g. desks, chairs)	0.28	0.24	Non-ICT M&E
2	Non-office furniture, furnishings & fixtures (e.g. recreational equip.)	0.14	0.21	Non-ICT M&E
3	Motors, generators, and transformers	0.11	0.13	Non-ICT M&E
4	Computer-assisted process	0.13	0.17	Non-ICT M&E
5	Non-computer-assisted process	0.11	0.16	Non-ICT M&E
6	Communication equipment	0.13	0.22	ICT
7	Tractors and heavy construction equipment	0.17	0.17	Non-ICT M&E
8	Computers, associated hardware & word processors	0.41	0.47	ICT
9	Trucks, vans, truck tractors, truck trailers & major replacement parts	0.19	0.23	Non-ICT M&E
10	Automobiles and major replacement parts	0.26	0.28	Non-ICT M&E
11	Other machinery and equipment	0.13	0.20	Non-ICT M&E
12	Electrical equipment and scientific devices	0.18	0.22	Non-ICT M&E
13	Other transportation equipment	0.09	0.10	Non-ICT M&E
14	Software	0.56	0.55	ICT
15	Plants for manufacturing	0.03	0.09	Bldg
16	Farm building, maintenance garages, and warehouses	0.02	0.08	Bldg
17	Office buildings	0.02	0.06	Bldg
18	Shopping centers and accommodations	0.03	0.07	Bldg
19	Passenger terminals, warehouses	0.03	0.07	Bldg
20	Other buildings	0.03	0.06	Bldg
21	Institutional building construction	0.02	0.06	Bldg
22	Transportation engineering construction	0.02	0.07	Eng
23	Electric power engineering construction	0.02	0.06	Eng
24	Communication engineering construction	0.03	0.12	Eng
25	Downstream oil and gas engineering facilities	0.04	0.07	Eng
26	Upstream oil and gas engineering facilities	0.05	0.13	Eng
27	Other engineering construction	0.02	0.08	Eng
Simple Average				
ICTs		0.37	0.41	
Non-ICT M&E		0.15	0.19	
Building Construction		0.03	0.07	
Engineering Construction		0.03	0.09	
Total Assets		0.12	0.16	

Sources: Statistics Canada for Canada and authors' calculations based on BEA data for the United States.

Canada, the labour matrix is from Statistics Canada, and for the United States, it is from the EUKLEMS database, which is developed by Dale Jorgenson and his associates.[9]

Capital Services

Capital input measures the services from using capital stock. It is aggregated over different types of capital stock (i.e. M&E and structures), with user costs of capital as weights.[10] Capital stock of

9 For the United States, the labour matrix only goes up to 2005. We extend the labour quality data from 2005 to 2010 using the labour quality index from the U.S. Bureau of Labor Statistics.

Table 4
Growth in Capital Services by Industry in Canada and the United States, 1987-2010
(average annual growth rate, per cent)

	Canada					United States			
	Ind1	**Ind2**	**Ind3**	**Ind4**		**Ind1**	**Ind2**	**Ind3**	**Ind4**
Agriculture, forestry, fishing, and hunting	-1.1	-1.2	-0.5	-0.5		0.6	0.6	0.6	0.6
Mining and oil and gas extraction	4.4	4.4	4.5	4.4		0.8	0.8	0.9	0.9
Oil and gas extraction	4.8	4.8	4.9	4.8		0.8	1.0	1.0	1.1
Mining	2.6	2.5	2.7	2.5		0.5	0.4	0.5	0.4
Utilities	1.3	1.2	1.6	1.5		1.4	1.2	1.7	1.6
Construction	4.1	4.0	4.1	4.0		4.2	4.1	4.3	4.2
Manufacturing	1.3	1.2	1.7	1.6		2.0	1.9	2.2	2.0
Wood products	1.1	1.1	1.8	1.6		-0.6	-0.7	0.0	-0.2
Non-metallic mineral products	1.4	1.3	1.3	1.2		0.6	0.5	0.6	0.5
Primary metals	-0.7	-0.8	0.2	0.2		-0.2	-0.4	-0.3	-0.4
Fabricated metal products	1.1	1.1	1.4	1.4		1.0	1.0	1.3	1.2
Machinery	2.2	2.1	2.4	2.3		1.9	1.8	2.3	2.2
Computer and electronic products	1.3	1.2	2.2	2.1		4.6	4.3	5.0	4.7
Electrical equipment, appliances, and components	0.9	0.8	1.3	1.3		-0.4	-0.4	0.6	0.5
Motor vehicles, bodies and trailers, and others	2.0	1.9	2.9	2.7		2.4	2.2	2.7	2.5
Furniture and related products, and miscellaneous	3.3	3.2	3.5	3.4		1.9	1.8	2.1	2.0
Food, beverage, and tobacco products	1.1	1.0	1.1	1.0		1.1	1.1	1.4	1.3
Textile mills and textile product mills	-2.1	-2.2	-1.1	-1.0		-2.8	-2.9	-1.4	-1.5
Apparel and leather and allied products	-1.6	-1.7	-0.6	-0.6		-1.6	-1.7	-0.4	-0.4
Paper products, printing and related support activities	-0.9	-1.0	0.1	0.0		-0.4	-0.5	0.4	0.3
Petroleum and coal products	4.2	3.4	4.3	3.5		2.8	2.7	2.1	2.0
Chemical products	-0.5	-0.5	0.3	0.3		2.4	2.3	2.6	2.5
Plastics and rubber products	2.5	2.4	2.9	2.8		1.8	1.8	2.2	2.2
Wholesale trade	6.5	6.4	5.8	5.6		3.2	3.1	3.6	3.4
Retail trade	6.2	6.0	5.7	5.5		4.0	3.8	4.2	4.0
Transportation and warehousing	3.8	3.6	3.4	3.1		1.8	1.5	1.5	1.0
Information	4.9	4.8	5.1	4.9		5.6	5.1	5.8	5.5
FIRE, management of companies and enterprises	4.0	3.7	4.5	4.2		3.9	3.7	4.5	4.3
Professional, scientific, and technical services	13.9	13.7	13.7	13.4		8.8	8.6	8.3	8.2
Administrative and waste management	7.4	7.2	4.7	4.4		5.5	5.3	5.7	5.5
Education and health care and social assistance	4.2	4.0	3.4	3.1		5.1	4.9	5.0	4.8
Arts, entertainment, and recreation	6.3	6.0	6.5	6.2		5.4	5.4	4.8	4.7
Accommodation and food services	3.2	3.1	3.7	3.6		2.2	2.2	2.4	2.4
Other services (except public admin)	5.4	5.1	3.0	2.6		2.6	2.5	2.6	2.5
Correlations by Approach									
Ind1: StatCan depreciation, equal nominal rate of return	1.000	0.999	0.971	0.964		1.000	0.999	0.985	0.984
Ind2: StatCan depreciation, equal real rate of return		1.000	0.972	0.967			1.000	0.983	0.984
Ind3: BEA depreciation, equal nominal rate of return			1.000	0.998				1.000	0.999
Ind4: BEA depreciation, equal real rate of return				1.000					1.000

Table 5

MFP Growth by Industry in Canada and the United States, 1987-2010

(average annual growth rate, per cent)

	Canada					United States			
	Ind1	**Ind2**	**Ind3**	**Ind4**		**Ind1**	**Ind2**	**Ind3**	**Ind4**
Agriculture, forestry, fishing, and hunting	3.1	3.1	2.7	2.7		2.1	2.1	2.1	2.1
Mining and oil and gas extraction	-2.1	-2.1	-2.1	-2.1		-0.7	-0.7	-0.7	-0.7
Oil and gas extraction	-2.5	-2.5	-2.5	-2.5		-2.7	-2.8	-2.7	-2.8
Mining	-1.0	-0.9	-1.0	-0.9		1.1	1.2	1.2	1.2
Utilities	-0.1	0.0	-0.3	-0.2		-0.3	-0.2	-0.5	-0.4
Construction	-0.8	-0.7	-0.8	-0.7		-2.2	-2.2	-2.2	-2.2
Manufacturing	1.2	1.2	1.0	1.0		2.6	2.7	2.6	2.6
Wood products	2.1	2.1	1.9	1.9		0.5	0.5	0.5	0.5
Non-metallic mineral products	0.1	0.2	0.2	0.3		0.0	0.1	0.1	0.1
Primary metals	3.0	3.0	2.7	2.7		0.7	0.7	0.8	0.8
Fabricated metal products	0.3	0.3	0.2	0.2		0.0	0.1	0.0	0.0
Machinery	1.0	1.0	0.9	0.9		1.1	1.1	1.0	1.0
Computer and electronic products	2.8	2.9	2.7	2.7		19.6	19.7	19.5	19.6
Electrical equipment, appliances, and components	-0.2	-0.2	-0.3	-0.2		0.8	0.9	0.5	0.5
Motor vehicles, bodies and trailers, and others	1.9	1.9	1.6	1.6		-0.3	-0.3	-0.4	-0.3
Furniture and related products, and miscellaneous	0.2	0.3	0.2	0.2		3.3	3.3	3.2	3.2
Food, beverage, and tobacco products	0.3	0.3	0.3	0.3		0.0	0.0	-0.2	-0.1
Textile mills and textile product mills	0.4	0.4	0.1	0.1		3.3	3.3	2.9	2.9
Apparel and leather and allied products	0.5	0.5	0.3	0.3		3.6	3.6	3.3	3.3
Paper products, printing and related support activities	0.9	0.9	0.6	0.6		0.7	0.7	0.5	0.5
Petroleum and coal products	-1.4	-1.1	-1.4	-0.9		3.3	3.4	3.9	4.0
Chemical products	1.6	1.6	1.2	1.2		-0.3	-0.3	-0.4	-0.4
Plastics and rubber products	1.0	1.0	0.9	0.9		1.6	1.6	1.4	1.4
Wholesale trade	1.2	1.2	1.4	1.4		2.5	2.5	2.4	2.4
Retail trade	1.7	1.7	1.7	1.8		2.0	2.0	1.9	2.0
Transportation and warehousing	0.0	0.0	0.1	0.2		1.5	1.6	1.7	1.8
Information	0.5	0.6	0.4	0.5		1.9	2.1	1.7	1.9
FIRE, management of companies and enterprises	0.2	0.3	-0.1	0.1		-0.2	-0.1	-0.6	-0.5
Professional, scientific, and technical services	-1.5	-1.5	-1.5	-1.4		-1.1	-1.0	-0.9	-0.9
Administrative and waste management	0.0	0.0	0.5	0.6		0.7	0.7	0.6	0.7
Education and health care and social assistance	-1.5	-1.5	-1.4	-1.3		-1.7	-1.7	-1.7	-1.7
Arts, entertainment, and recreation	-1.7	-1.6	-1.8	-1.7		-0.5	-0.4	-0.2	-0.2
Accommodation and food services	0.0	0.0	-0.1	-0.1		0.4	0.4	0.3	0.3
Other services (except public admin)	-1.1	-1.1	-0.8	-0.7		-1.3	-1.3	-1.3	-1.3
Correlations by Approach									
Ind1: StatCan depreciation, equal nominal rate of return	1.000	0.999	0.991	0.989		1.000	1.000	0.999	0.999
Ind2: StatCan depreciation, equal real rate of return		1.000	0.990	0.990			1.000	0.999	0.999
Ind3: BEA depreciation, equal nominal rate of return			1.000	0.998				1.000	1.000
Ind4: BEA depreciation, equal real rate of return				1.000					1.000

a particular asset is estimated using the perpetual inventory method. It equals capital stock in the previous year (after depreciation) plus new investment in the current year (both in real terms). The perpetual inventory method of estimating capital stock implies that the estimate of capital stock is sensitive to the depreciation rate.

Capital Stock

Before 2006, Statistics Canada more or less followed the BEA and produced Canada's capital stock estimates under the geometric depreciation profile. The estimates were thus fairly comparable to the BEA capital stock estimates. After November 2006, however, Statistics Canada has followed the new depreciation rates estimated by Statistics Canada (2007).[11] Basically, under the new geometric depreciation profile, the declining balance rates are significantly larger, and the services' lives are significantly shorter than the ones used by BEA. As a result, the new depreciation rates are generally larger than the old rates, especially for structures.

Table 3 reports Statistics Canada's new depreciation rates and the implicit BEA depreciation rates for 27 Canadian assets. The resulting new Canadian depreciation rates are, on average, higher than those used by the BEA for information and communication technology (ICT) equipments (41 per cent vs. 37 per cent); non-ICT M&E (19 per cent vs. 15 per cent); building construction (7 per cent vs. 3 per cent); and engineering construction (9 per cent vs. 3 per cent).

Because of the substantial difference in depreciation rates between Canada and the United States, the official capital stock estimates, especially in terms of levels, are not comparable between the two countries. To resolve this problem, this article uses both Statistics Canada and BEA depreciation rates to estimate capital stock for both Canada and the United States.

The investment data used in generating non-residential capital stock estimates in Canada are based on investment surveys, which are conducted by the Investment and Capital Stock Division (ICSD) at Statistics Canada. These data are based on the North American Industry Classification System (NAICS) and contain investment in current dollars as well as chained Fisher volume indices over the 1961-2010 period for 175 assets. To simplify our analysis, we aggregate the 175 assets into 27 asset types listed in Table 3.

The investment data for estimating non-residential capital stock in the United States are from the BEA.[12] These data contain investment at the NAICS industry level for 74 assets over the period of 1901-2010. For a comparison purpose, we also group the 74 assets into 27 asset types.

User Cost of Capital

As its name suggests, user cost of capital is the cost of using capital. Following the EUKLEMS program, we define it as[13]

10 We do not have comparable data on land by industry for both Canada and the United States. Following the EUKLEMS program and for simplicity, we exclude both land and inventories. Baldwin and Gu (2013) show that the MFP estimate for the Canadian business sector in the 1981-2011 period was 0.1 percentage points lower when land and inventories are included. This is because inventories are a small component of total capital stock and land capital stock grows at a slow pace.

11 That study is based on a Canadian micro database on the purchase and disposal of capital goods from Statistics Canada's Capital Expenditure Survey, which consists of data on the selling value of used assets, the age of the assets, and the corresponding gross book value as well as the expected service lives of new assets. For other research on this topic, see Gellatly, Tanguay, and Yan (2002), and Patry (2007).

12 www.bea.gov/national/FA2004/Details/Index.html

13 In this article, following the practice by EUKLEMS (www.euklems.net/) for estimating the user cost of capital for international comparisons, we exclude the tax parameter, which is different from Statistics Canada's MFP program and Diewert and Yu (2012). There are three reasons for the exclusion. First, we do not have comparable data on tax for the United States. Second, our capital compensation is at factor cost, excluding tax on production and products. Finally, it is not an important factor for the user cost of capital since capital service estimates without the tax parameter are very similar to estimates with the tax parameter, based on a calculation using the CPP data.

Table 6

MFP Growth Difference by Industry in Canada and the United States, 1987-2010

(percentage points)

	Diff (US-Canada)			
	Ind1	**Ind2**	**Ind3**	**Ind4**
Agriculture, forestry, fishing, and hunting	-0.9	-0.9	-0.6	-0.6
Mining and oil and gas extraction	1.5	1.4	1.5	1.4
Oil and gas extraction	-0.2	-0.3	-0.2	-0.4
Mining	2.1	2.1	2.1	2.1
Utilities	-0.3	-0.2	-0.2	-0.2
Construction	-1.5	-1.5	-1.5	-1.5
Manufacturing	1.5	1.5	1.6	1.6
Wood products	-1.5	-1.5	-1.4	-1.4
Non-metallic mineral products	-0.1	-0.1	-0.2	-0.2
Primary metals	-2.3	-2.3	-1.9	-1.9
Fabricated metal products	-0.2	-0.2	-0.2	-0.2
Machinery	0.1	0.2	0.1	0.1
Computer and electronic products	16.8	16.8	16.8	16.8
Electrical equipment, appliances, and components	1.0	1.0	0.8	0.8
Motor vehicles, bodies and trailers, and others	-2.2	-2.2	-2.0	-2.0
Furniture and related products, and miscellaneous	3.0	3.0	2.9	3.0
Food, beverage, and tobacco products	-0.3	-0.3	-0.4	-0.4
Textile mills and textile product mills	2.9	2.9	2.8	2.8
Apparel and leather and allied products	3.1	3.1	3.0	3.0
Paper products, printing and related support activities	-0.2	-0.2	-0.1	-0.1
Petroleum and coal products	4.7	4.4	5.3	4.9
Chemical products	-1.9	-1.9	-1.6	-1.6
Plastics and rubber products	0.6	0.5	0.5	0.5
Wholesale trade	1.3	1.3	1.0	1.0
Retail trade	0.3	0.3	0.2	0.2
Transportation and warehousing	1.6	1.6	1.6	1.6
Information	1.4	1.5	1.3	1.4
FIRE, management of companies and enterprises	-0.4	-0.4	-0.5	-0.5
Professional, scientific, and technical services	0.4	0.4	0.5	0.5
Administrative and waste management	0.7	0.7	0.1	0.1
Education and health care and social assistance	-0.2	-0.2	-0.3	-0.3
Arts, entertainment, and recreation	1.2	1.2	1.6	1.5
Accommodation and food services	0.3	0.3	0.4	0.4
Other services (except public admin)	-0.2	-0.2	-0.5	-0.5
Correlations by Approach				
Ind1: StatCan depreciation, equal nominal rate of return	1.000	1.000	0.998	0.998
Ind2: StatCan depreciation, equal real rate of return		1.000	0.997	0.998
Ind3: BEA depreciation, equal nominal rate of return			1.000	1.000
Ind4: BEA depreciation, equal real rate of return				1.000

Chart 3
Real GDP in the Canadian and U.S. Business Sector, 1987-2010
(2002=100)

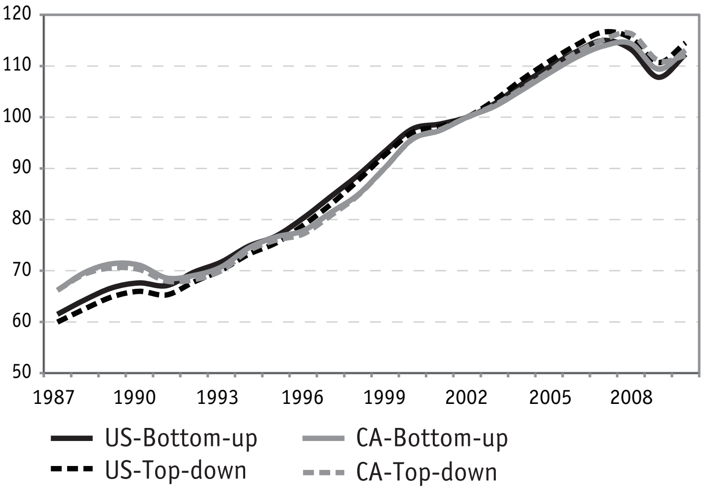
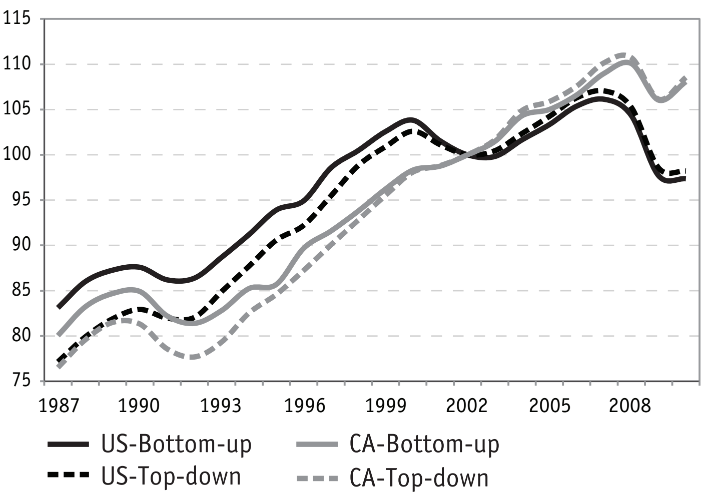


Chart 4
Labour Services in the Canadian and U.S. Business Sector, 1987-2010
(2002=100)



$$U_{ij}^t = (r_{ij}^t - \rho_{ij}^t + \delta_{ij}^t)p_{ij}^t$$

Where r_{ij}^t is the nominal rate of return to capital *j* in industry *i* at period *t*;

ρ_{ij}^t is the rate of price change in asset *j* in industry *i* at period *t*;

δ_{ij}^t is the depreciation rate for capital *j* in industry *i* at period *t*; and

p_{ij}^t is the investment price of asset *j* in industry *i* at period *t*;

There are different ways of estimating the user cost of capital. In this article, we follow two different approaches, currently adopted by the CPP at Statistics Canada and Diewert and Yu (2012), to test the sensitivity of MFP estimates to alternative methodologies. For both methods, the rate of return to capital is determined endogenously. That is, the sum of capital stock multiplied by user cost over all types of assets equals total capital compensation. The depreciation rate of an asset and the investment price of the asset are pre-determined. The nominal rate of return to capital and the rate of price change in an asset have to be estimated.

Statistics Canada assumes that the rate of price change in an asset can be approximated by the actual ex-post rate of price change in an asset. Assuming the nominal rate of return to capital to be the same for all assets within an industry, and the total user cost of capital to be equal to the actual ex-post total capital compensation of the industry, the CPP calculates the nominal rate of return to capital endogenously for the industry.

In contrast, Diewert and Yu (2012) believe that the actual ex-post rate of price change in asset is not a good proxy for the rate of price change in an asset because it is too volatile. Consequently, they assume that real rate of return to capital, which equals the nominal rate of return to capital minus the rate of price change in asset, is equal across all assets and all industries. They then calculate endogenously the real rate of return to capital, assuming, as in the CPP, that the sum of total user cost of capital is equal to the actual ex-post total capital compensation for the business sector.

Table 7
MFP Growth in the Canadian and the U.S. Business Sector
(average annual growth rate, per cent)

	Canada			United States		
	1987-2000	2000-2010	1987-2010	1987-2000	2000-2010	1987-2010
Bottom-up Approach						
Value Added	2.84	1.67	2.33	3.56	1.39	2.62
Labour Services	1.67	1.01	1.38	1.71	-0.64	0.69
***Bus1*: Bottom-up, StatCan asset depreciation rates, and equal nominal rates of return to capital**						
Capital Services	3.90	3.32	3.65	5.01	2.01	3.71
MFP	0.44	-0.19	0.17	0.60	1.03	0.78
***Bus2*: Bottom-up, StatCan asset depreciation rates, and equal real rates of return to capital**						
Capital Services	3.76	3.18	3.51	4.77	1.94	3.54
MFP	0.48	-0.14	0.21	0.69	1.05	0.85
***Bus3*: Bottom-up, BEA asset depreciation rates, and equal nominal rates of return to capital**						
Capital Services	3.93	3.43	3.71	5.06	2.43	3.92
MFP	0.43	-0.23	0.15	0.58	0.86	0.70
***Bus4*: Bottom-up, BEA asset depreciation rates, and real nominal rates of return to capital**						
Capital Services	3.77	3.25	3.54	4.80	2.36	3.74
MFP	0.49	-0.16	0.21	0.68	0.89	0.77
Top-down Approach						
Value Added	2.84	1.58	2.29	3.70	1.66	2.81
Labour Services	2.06	1.21	1.69	2.19	-0.44	1.05
***Bus5*: Top-down, StatCan asset depreciation rates, and equal nominal rates of return to capital**						
Capital Services	3.38	3.29	3.34	4.51	1.91	3.38
MFP	0.27	-0.42	-0.03	0.56	1.18	0.83
***Bus6*: Top-down, StatCan asset depreciation rates, and equal real rates of return to capital**						
Capital Services	3.20	3.17	3.19	4.29	1.81	3.21
MFP	0.32	-0.39	0.01	0.64	1.21	0.89
***Bus7*: Top-down, BEA asset depreciation rates, and equal nominal rates of return to capital**						
Capital Services	3.52	3.24	3.40	4.35	2.23	3.43
MFP	0.24	-0.40	-0.03	0.62	1.06	0.81
***Bus8*: Top-down, BEA asset depreciation rates, and equal real rates of return to capital**						
Capital Services	3.30	3.09	3.21	4.08	2.11	3.22
MFP	0.31	-0.35	0.02	0.71	1.10	0.88

Discussion of the Results

In this section, we compare and contrast MFP growth estimates based on different methodologies, with a focus on the implication of MFP trend growth in Canada and the Canada-U.S. MFP growth gap.

MFP Growth by Industry

At the industry level, there are four scenarios for each country, corresponding to combinations of the two sets of asset depreciation rates (Statistics Canada or BEA) and two rate-of-return assumptions (equal nominal or real rate of return to capital across all assets). Thus, the four scenarios differ only in the estimation of capital services, with other variables being the same.

The capital services growth estimates under these four scenarios from 1987-2010 were in general similar, with the correlation coefficients being more than 0.964 for Canada and 0.983 for the United States (Table 4). The largest difference was in the use of different asset depreciation rates with Statistics Canada depreciation rates

Chart 5
Capital Services in the Canadian Business Sector, 1987-2010
(2002=100)

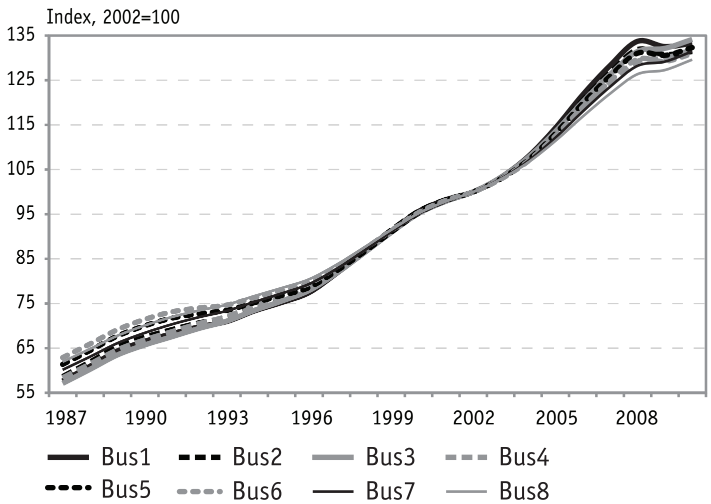
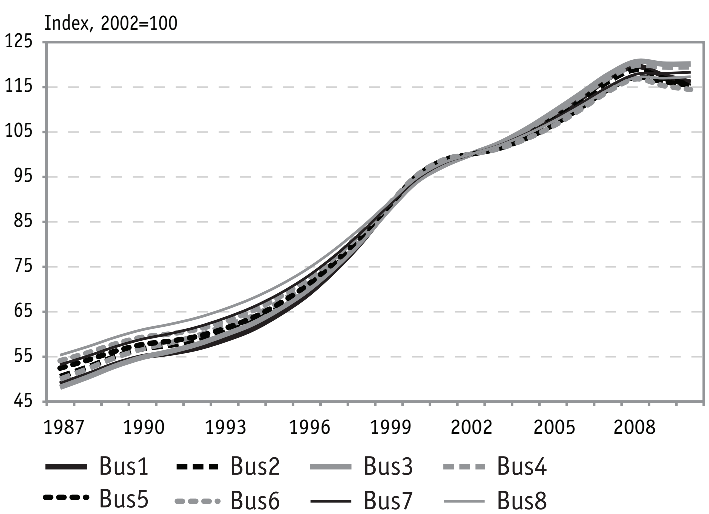


Chart 6
Capital Services in the U.S. Business Sector, 1987-2010
(2002=100)



being applied to Ind1 and Ind2 and BEA depreciation rates to Ind3 and Ind4. In contrast, the growth estimates in capital service based on the assumption of an equal nominal rate of return to capital across all assets were very close to those based on the assumption of an equal real rate of return to capital (Ind1 vs. Ind2 and Ind3 vs. Ind4).

Because of the similar growth estimates in capital services, the MFP estimates by industry from 1987-2010 in the four scenarios were also similar for most industries (Table 5).[14] Interestingly similar patterns in capital service emerge for both countries. The estimates under Ind1 were almost identical to those under Ind2, and Ind3 estimates were almost identical to those under Ind4, with the correlation coefficients being almost one for both Canada and the United States. This, in turn, suggests that MFP growth estimates are not sensitive to different assumptions on the rate of return to capital. The pattern seems to hold in general for the 1987-2000 and 2000-2010 sub-periods.[15]

In addition, the difference in MFP growth rate between Canada and the United States is found to be fairly similar across the four scenarios for most industries, with the correlation coefficients being almost one between any two scenarios of the four (Table 6).

These results suggest that the MFP growth estimates are fairly robust to different choices of asset depreciation rates, and especially to different assumptions on the rate of return to capital.[16]

MFP Growth in the Business Sector

In addition to the choice of asset depreciation rates and the different assumptions with respect to the rates of return to capital, we can also choose between the bottom-up and the top-down

14 See Table A1 in the Appendix for labour productivity growth by industry for 1987-2000, 2000-2010 and 1987-2010.

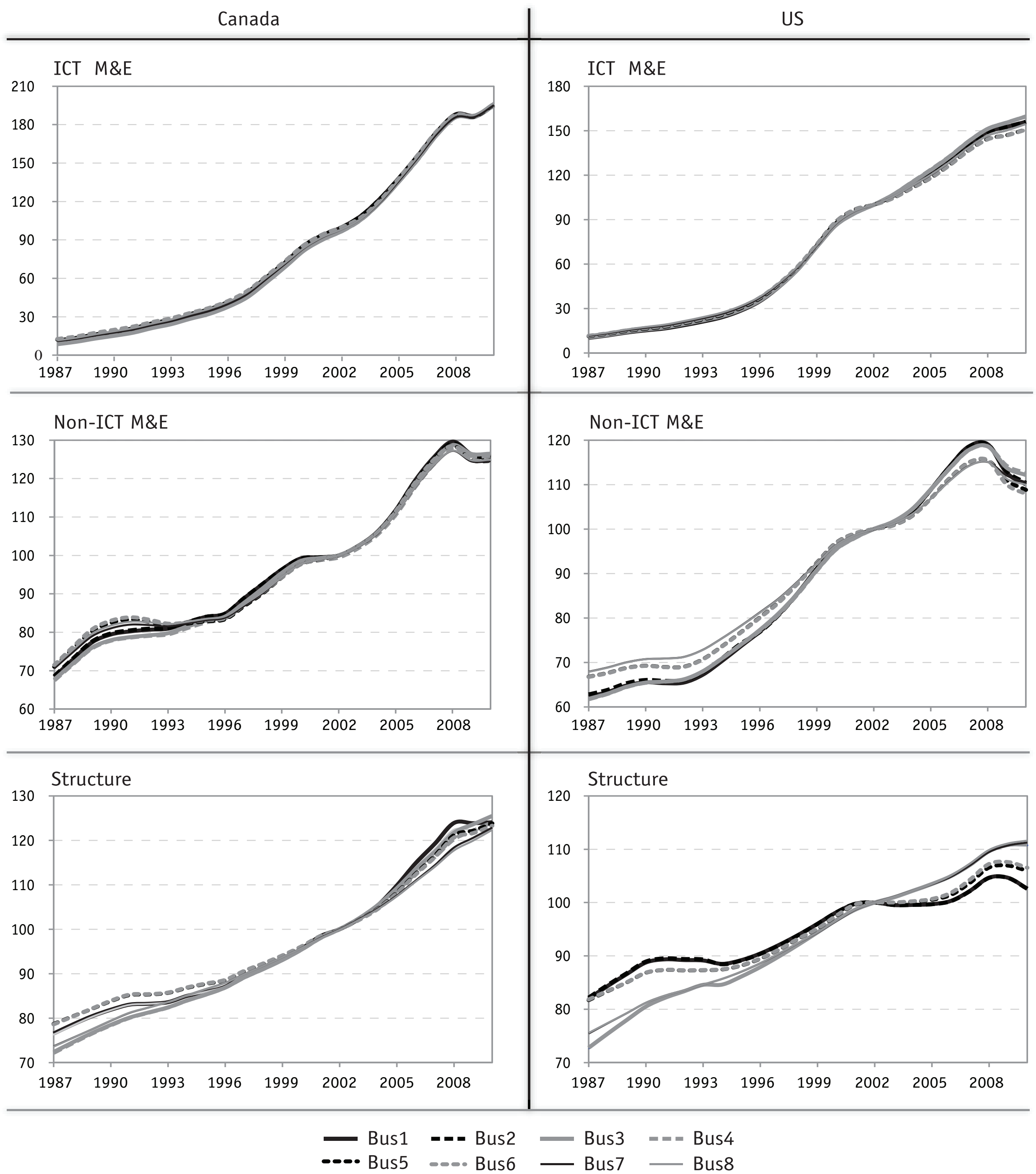
15 MFP growth rate estimates for the two sub-periods are reported in Tables A2 and A3 in Appendix.

16 The finding on different asset depreciation rates is also consistent with Tang, Rao, and Li. (2010) showing MFP estimates to be generally similar when the two different sets of asset depreciation rates are used to estimate capital stock.

Chart 7

Trends in Capital Services in the Canadian and the U.S. Business Sector, 1987-2010

(2002=100)



approaches at the business sector level. As discussed in the previous section, we have eight different scenarios.

Real GDP based on the bottom-up approach was in general similar to that based on the top-down approach (Chart 3) for both

Chart 8
MFP in the Canadian Business Sector, 1987-2010
(2002=100)

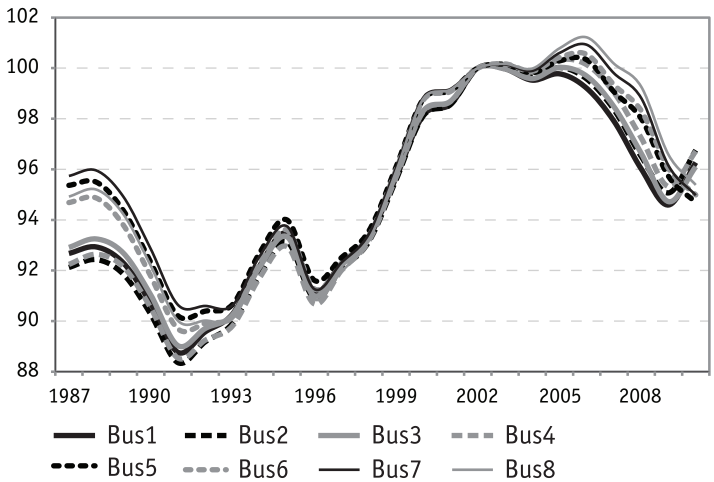
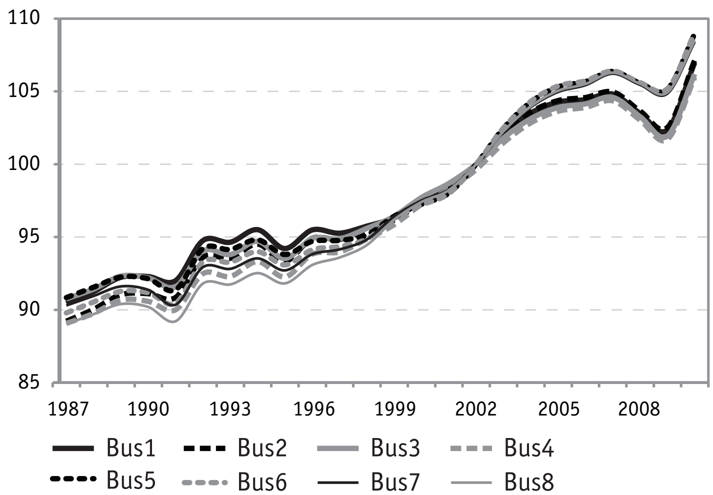


Chart 9
MFP in the U.S. Business Sector, 1987-2010
(2002=100)



Canada and the United States. In Canada, real GDP based on the bottom-up and the top-down approaches grew almost at the same pace of 2.3 per cent per year over the period of 1987-2010 (Table 7). In the United States, real GDP based on the bottom-up approach grew 2.6 per cent per year, as opposed to 2.8 per cent per year based on the top-down approach. This small difference was mainly driven by the difference in 2000-2010. In this sub-period, real GDP based on the bottom-up approach grew at 1.4 per cent per year, as opposed to 1.7 per cent per year based on the top-down approach.

The growth estimate for labour services was higher by the top-down approach than by the bottom-up approach for both Canada and the United States (Chart 4). Over the period 1987-2010, labour services by the top-down approach in Canada grew at 1.7 per cent per year as opposed to 1.4 per cent per year by the bottom-up approach—a difference of 0.3 percentage points per year (Table 7). For the United States, labour services grew at 1.1 per cent per year by the top-down approach and 0.7 per cent per year by the bottom-up approach—a difference of 0.4 percentage points per year. Most of the difference appeared to be in the pre-2000 sub-period in both countries. The difference suggests that industries with relatively high growth in labour input paid relatively lower labour compensation (e.g. wages) than industries with relatively low labour growth. As labour compensation for the same type of worker is generally higher in the manufacturing sector than in the service sector, this result may reflect the long-term trend that the economies shift from the manufacturing sector to the service sector.

Capital service estimates in the eight scenarios are summarized in Charts 5 and 6 for Canada and the United States, respectively. In general, the largest difference was due to the choice of different approaches. Capital service grew faster by the bottom-up approach (in solid lines) than by the top-down approach (in dash lines). For Canada, capital service based on the bottom-up approach grew at a rate between 3.5-3.7 per cent per year in 1987-2010 while it grew at 3.2-3.4 per cent per year by the top-down approach. For the United States, it grew at 3.5-3.9 per cent per year by the bottom-up approach and 3.2-3.4 per cent per year by the top-down approach. This

Table 8
MFP Growth Difference between 1987-2000 and 2000-2010 in the Canadian and the U.S. Business Sector
(average percentage points per year)

	Canada	United States
Bottom-up Approach		
Bus1: StatCan depreciation and equal nominal rate of return	-0.63	0.43
Bus2: StatCan depreciation and equal real rate of return	-0.62	0.36
Bus3: BEA depreciation and equal nominal rate of return	-0.66	0.28
Bus4: BEA depreciation and equal real rate of return	-0.65	0.21
Top-down Approach		
Bus5: StatCan depreciation and equal nominal rate of return	-0.69	0.62
Bus6: StatCan depreciation and equal real rate of return	-0.71	0.57
Bus7: BEA depreciation and equal nominal rate of return	-0.64	0.44
Bus8: BEA depreciation and equal real rate of return	-0.66	0.39

Table 9
MFP Growth Difference between the Canadian and the U.S. Business Sector
(average percentage points per year)

	US-Canada		
	1987-2000	2000-2010	1987-2010
Bottom-up Approach			
Bus1: StatCan depreciation and equal nominal rate of return	0.16	1.22	0.61
Bus2: StatCan depreciation and equal real rate of return	0.21	1.19	0.64
Bus3: BEA depreciation and equal nominal rate of return	0.15	1.09	0.55
Bus4: BEA depreciation and equal real rate of return	0.19	1.05	0.56
Top-down Approach			
Bus5: StatCan depreciation and equal nominal rate of return	0.29	1.60	0.86
Bus6: StatCan depreciation and equal real rate of return	0.32	1.60	0.88
Bus7: BEA depreciation and equal nominal rate of return	0.38	1.46	0.84
Bus8: BEA depreciation and equal real rate of return	0.40	1.45	0.86

result is consistent with the finding of Diewert and Yu (2012) and Gu (2012) for Canada.[17] These findings suggest that in both countries, industries with faster growth in capital services also tend to maintain higher rates of return to capital, indicating that industries with high growth in capital input are likely to be more profitable.

As shown in Chart 7, ICT capital services in the eight scenarios were fairly close to one another, especially for Canada. The differences in total capital services among these scenarios were to a large extent caused by other capital assets, especially structures.

MFP growth represents the residual of real GDP growth that cannot be explained by com-

17 However, the variation between different scenarios is much smaller compared to that between the CPP and Diewert and Yu (2012). In the period 1987-2010, capital services grew 3.7 per cent per year according to the CPP and 2.2 per cent per year according to Diewert-Yu, a difference of 1.5 percentage points. In contrast, the difference in capital services growth between our scenarios is relatively smaller, as capital services for Canada grew at a range of 3.2-3.7 per cent per year, depending on the scenarios. It is likely that the difference between the CPP and Diewert and Yu also reflects variations in the underlying data.

bined labour and capital input growth. MFP growth estimates corresponding to these eight scenarios are reported in Chart 8 for Canada and in Chart 9 for the United States.[18]

For Canada, the MFP estimates by the bottom-up approach (in solid lines) grew at a more rapid pace than those by the top-down approach (in dashed lines). This was because, under the bottom-up approach, real GDP grew faster while labour services grew slower in the post-2000 period (Table 7). For the United States, the opposite was true: the MFP estimates based on the bottom-up approach grew slower than those based on the top-down approach. Under the bottom-up approach, real GDP for the United States grew slower while capital services grew faster (especially for the 1987-2000 period). The difference in MFP estimates between the two countries may reflect, in large part, the difference in industry structures and industry dynamics between the two countries.

By comparing Chart 8 to Chart 9, we observe a more volatile MFP growth in Canada than in the United States. This may capture the fact that Canada, as a small open economy that concentrates in resource-based industries, is more sensitive to external shocks and volatile commodity prices.

Despite the differences across different scenarios, MFP growth estimates in the business sector were fairly robust to alternative assumptions and methodologies (Table 7). This was the case for both countries. For the Canadian business sector in the 1987-2010 period, the highest and lowest MFP growth estimates were 0.21 and -0.03 per cent per year, respectively, with a difference of 0.24 percentage points. For the U.S. business sector, the highest and lowest MFP growth estimates were 0.89 and 0.70 per cent per year, respectively, with a difference of 0.19 percentage points. In the 1987-2000 and 2000-2010 sub-periods, the difference between the highest and the lowest MFP estimates was 0.28 percentage points for Canada and 0.35 percentage points for the United States.

Table 8 shows that the MFP growth differential between 1987-2000 and 2000-2010 was robust to alternative assumptions and methodologies, especially for Canada, where it averaged -0.66 percentage points across the eight scenarios—ranging from -0.71 percentage points (Bus6) to -0.62 percentage points (Bus2). For the United States, the MFP growth differential averaged 0.41 percentage points, ranging from 0.21 percentage points (Bus4) to 0.62 percentage points (Bus5). Regardless of the methodology adopted, these estimates show that Canada's weak MFP performance (compared to that of the United States) became even more pronounced in the post-2000 period (Table 9).

Conclusions

There is no question that different methodologies produce different MFP growth estimates due to inefficient input markets and heterogeneous industries. The real question is: how different are they? In this article, we studied the sensitivity of MFP growth rates to alternative methodologies by industry and by the business sector for both Canada and the United States.

We started the investigation on an equal footing for both Canada and the United States with fairly comparable raw data, including information on 18 types of workers and 27 different asset types at the industry level. We considered three alternative methodologies/assumptions in estimating output and inputs: Statistics Canada and BEA asset deprecation rates (for capital services), equal nominal or real rates of return of capital across all assets (for capital services), and the top-down or the bottom-up approach (for aggregation).

18 For labour productivity growth and its contributors in the business sector for 1987-2000, 2000-2010 and 1987-2010, see Table A4 for Canada and Table A5 for the United States.

We found that MFP growth estimates under these alternative methodologies can vary, and yet the differences are relatively small. We showed that the MFP growth estimates are in general robust to the choice of methodologies and assumptions. The robustness checks confirm that MFP growth in Canada has indeed slowed in the post-2000 period (especially after 2005) and that the United States has outperformed Canada by a wide margin over this period.

Our capital and labour services indexes based on the bottom-up approach for the business sector are in general consistent with the CPP estimates at Statistics Canada. However, a comparison has to be made with caution since there are several major differences in the two estimations. First, the CPP uses much more disaggregated data on asset type, labour composition and industry classification. Second, value added in our analysis is measured at factor cost while it is measured at basic prices under the CPP. Third, our classification of workers is the same as that in the EUKLEMS program, but it differs from the CPP. In particular, we have three types of education levels while the CPP uses five. Fourth, our investment data are directly from the Investment and Capital Stock Division (ICSD) at Statistics Canada. For the CPP, they are benchmarked to the investment estimates in the final demand matrix of the input/output tables. Finally, following the EUKLEMS program, we exclude land and inventory in our capital input estimation, while they are included by the CPP.

It is also important to note that for our analysis, the underlying data and their sources are the same for all scenarios discussed. MFP growth estimates could well be different when raw data are different. In addition, our scenarios, which are based on three different methodological assumptions, are not exhaustive. For future research, the robustness check performed here could be extended to include greater levels of detail in terms of asset type, labour composition or industry classifications, although we do not expect that the new effort will produce substantially different MFP growth estimates.

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Appendix Tables

Table A1

Labour Productivity Growth by Industry in Canada and the United States, 1987-2010
(average annual growth rate, per cent)

	Canada			United States		
	1987-2000	2000-2010	1987-2010	1987-2000	2000-2010	1987-2010
Agriculture, forestry, fishing, and hunting	3.4	3.7	3.6	4.3	2.5	3.5
Mining and oil and gas extraction	2.0	-2.8	-0.1	2.0	-2.6	0.0
Oil and gas extraction	4.5	-5.6	0.1	-0.5	-1.7	-1.0
Mining	0.6	-1.4	-0.2	6.1	-3.7	1.8
Utilities	0.0	0.0	0.0	2.8	-0.3	1.5
Construction	-0.4	0.0	-0.2	0.1	-1.8	-0.7
Manufacturing	3.2	0.9	2.2	3.7	5.5	4.5
Wood products	1.6	5.3	3.2	-1.9	5.1	1.2
Non-metallic mineral products	1.6	0.6	1.2	1.9	-0.1	1.0
Primary metals	4.7	2.4	3.7	2.5	0.9	1.8
Fabricated metal products	1.2	-0.6	0.4	1.0	0.8	0.9
Machinery	2.6	0.7	1.8	0.6	5.0	2.5
Computer and electronic products	9.5	-2.0	4.5	21.7	21.6	21.6
Electrical equipment, appliances, and components	3.6	-2.1	1.1	1.0	4.0	2.3
Motor vehicles, bodies and trailers, and others	4.9	0.9	3.2	-0.1	0.5	0.2
Furniture and related products, and miscellaneous	2.7	-0.5	1.3	3.0	5.6	4.2
Food, beverage, and tobacco products	1.5	0.4	1.0	0.8	0.8	0.8
Textile mills and textile product mills	1.1	1.2	1.2	3.4	6.5	4.7
Apparel and leather and allied products	2.0	0.4	1.3	3.5	10.1	6.4
Paper products, printing and related support activities	2.0	0.5	1.3	-0.1	2.2	0.9
Petroleum and coal products	3.3	-2.5	0.8	6.3	7.4	6.8
Chemical products	4.1	-1.0	1.9	1.2	2.5	1.7
Plastics and rubber products	2.8	0.7	1.9	3.2	2.5	2.9
Wholesale trade	2.6	3.1	2.9	4.7	2.7	3.8
Retail trade	3.0	2.5	2.8	3.9	2.3	3.2
Transportation and warehousing	1.0	1.0	1.0	1.8	1.9	1.8
Information	2.0	2.2	2.1	1.4	8.5	4.5
FIRE, management of companies and enterprises	1.4	1.5	1.4	2.0	1.6	1.8
Professional, scientific, and technical services	0.2	0.5	0.3	0.7	2.1	1.3
Administrative and waste management	1.4	0.0	0.8	0.2	2.8	1.4
Education and health care and social assistance	-2.1	-0.1	-1.2	-1.8	0.4	-0.9
Arts, entertainment, and recreation	-0.8	-0.9	-0.8	1.0	0.7	0.9
Accommodation and food services	0.7	0.5	0.6	1.0	0.6	0.8
Other services (except public admin)	-1.0	0.8	-0.3	0.3	-1.7	-0.6
Business sector						
Bottom-up approach	1.3	0.7	1.0	1.8	2.1	1.9
Top-down approach	1.3	0.6	1.0	2.0	2.4	2.1

Note: Labour productivity is defined as real value added per hour worked.

Table A2

MFP Growth by Industry in Canada and the United States, 1987-2000

(average annual growth rate, per cent)

	Canada					United States			
	Ind1	**Ind2**	**Ind3**	**Ind4**		**Ind1**	**Ind2**	**Ind3**	**Ind4**
Agriculture, forestry, fishing, and hunting	3.6	3.6	3.2	3.2		3.5	3.6	3.3	3.3
Mining and oil and gas extraction	0.3	0.3	0.1	0.1		1.0	1.0	0.7	0.7
Oil and gas extraction	0.1	0.1	0.1	0.1		-3.0	-3.0	-3.4	-3.4
Mining	1.1	1.1	0.4	0.4		5.4	5.5	5.3	5.3
Utilities	0.3	0.4	-0.4	-0.3		1.7	1.7	1.0	1.0
Construction	-1.1	-1.1	-1.1	-1.1		-1.3	-1.3	-1.3	-1.2
Manufacturing	2.1	2.1	2.1	2.1		2.1	2.2	2.2	2.2
Wood products	0.8	0.8	0.9	1.0		-2.3	-2.3	-2.3	-2.2
Non-metallic mineral products	0.5	0.6	0.6	0.7		1.2	1.2	1.4	1.4
Primary metals	3.6	3.6	3.6	3.6		2.1	2.2	2.1	2.1
Fabricated metal products	1.4	1.4	1.4	1.4		0.2	0.2	0.2	0.3
Machinery	1.6	1.6	1.7	1.7		-1.3	-1.2	-1.2	-1.1
Computer and electronic products	7.2	7.3	7.3	7.4		19.2	19.3	19.3	19.4
Electrical equipment, appliances, and components	1.7	1.8	1.8	1.8		-0.4	-0.4	-0.7	-0.6
Motor vehicles, bodies and trailers, and others	3.6	3.6	3.4	3.4		-1.6	-1.6	-1.6	-1.5
Furniture and related products, and miscellaneous	1.9	1.9	2.0	2.0		1.8	1.9	1.9	1.9
Food, beverage, and tobacco products	0.2	0.2	0.3	0.3		0.1	0.1	0.0	0.0
Textile mills and textile product mills	0.5	0.5	0.4	0.4		2.4	2.4	2.3	2.4
Apparel and leather and allied products	1.1	1.2	1.1	1.1		0.8	0.8	0.8	0.8
Paper products, printing and related support activities	0.7	0.8	0.6	0.7		-1.0	-1.0	-1.1	-1.1
Petroleum and coal products	2.2	2.3	2.1	2.1		5.0	5.1	4.5	4.6
Chemical products	2.6	2.7	2.5	2.5		-1.6	-1.5	-1.4	-1.3
Plastics and rubber products	2.1	2.1	2.1	2.2		1.9	1.9	2.0	2.0
Wholesale trade	1.0	1.0	1.3	1.3		3.3	3.4	3.2	3.3
Retail trade	1.9	1.9	2.0	2.0		2.6	2.7	2.7	2.8
Transportation and warehousing	-0.1	0.0	0.1	0.2		1.1	1.3	1.4	1.7
Information	-0.1	-0.1	0.1	0.1		-0.9	-0.5	-0.8	-0.6
FIRE, management of companies and enterprises	-0.4	-0.3	-0.6	-0.5		-1.0	-0.9	-1.3	-1.1
Professional, scientific, and technical services	-2.5	-2.5	-2.4	-2.3		-1.9	-1.9	-1.6	-1.5
Administrative and waste management	0.9	1.0	1.3	1.4		-0.4	-0.3	-0.4	-0.4
Education and health care and social assistance	-2.2	-2.1	-2.1	-2.0		-2.3	-2.2	-2.3	-2.2
Arts, entertainment, and recreation	-1.8	-1.7	-1.9	-1.8		-0.5	-0.5	0.0	0.1
Accommodation and food services	0.3	0.3	0.1	0.1		0.7	0.7	0.6	0.6
Other services (except public admin)	-2.2	-2.1	-1.8	-1.7		-0.3	-0.2	-0.1	-0.1
Correlations by Approach									
Ind1: StatCan depreciation, equal nominal rate of return	1.000	1.000	0.992	0.992		1.000	1.000	0.998	0.998
Ind2: StatCan depreciation, equal real rate of return		1.000	0.992	0.992			1.000	0.998	0.998
Ind3: BEA depreciation, equal nominal rate of return			1.000	1.000				1.000	1.000
Ind4: BEA depreciation, equal real rate of return				1.000					1.000

Note: Labour productivity is defined as real value added per hour worked.

Table A3

MFP Growth by Industry in Canada and the United States, 2000-2010

(average annual growth rate, per cent)

	Canada				United States			
	Ind1	**Ind2**	**Ind3**	**Ind4**	**Ind1**	**Ind2**	**Ind3**	**Ind4**
Agriculture, forestry, fishing, and hunting	2.3	2.4	2.1	2.1	0.3	0.3	0.6	0.6
Mining and oil and gas extraction	-5.3	-5.2	-5.1	-5.0	-2.8	-2.9	-2.4	-2.6
Oil and gas extraction	-5.8	-5.8	-5.9	-5.8	-2.2	-2.5	-1.8	-2.2
Mining	-3.7	-3.5	-2.7	-2.5	-4.5	-4.4	-4.2	-4.1
Utilities	-0.5	-0.4	-0.2	-0.1	-2.9	-2.6	-2.4	-2.3
Construction	-0.3	-0.3	-0.3	-0.3	-3.4	-3.4	-3.5	-3.5
Manufacturing	-0.1	0.0	-0.4	-0.4	3.3	3.3	3.2	3.2
Wood products	3.7	3.7	3.1	3.1	4.2	4.2	4.0	4.0
Non-metallic mineral products	-0.4	-0.3	-0.3	-0.2	-1.5	-1.5	-1.6	-1.6
Primary metals	2.1	2.2	1.5	1.5	-1.2	-1.2	-0.9	-0.9
Fabricated metal products	-1.2	-1.2	-1.4	-1.3	-0.2	-0.2	-0.4	-0.4
Machinery	0.2	0.2	-0.1	-0.1	4.2	4.2	3.8	3.8
Computer and electronic products	-2.9	-2.9	-3.3	-3.3	20.1	20.2	19.8	19.8
Electrical equipment, appliances, and components	-2.7	-2.7	-2.9	-2.9	2.5	2.6	2.1	2.1
Motor vehicles, bodies and trailers, and others	-0.4	-0.3	-0.8	-0.7	1.4	1.4	1.2	1.2
Furniture and related products, and miscellaneous	-1.9	-1.8	-2.1	-2.1	5.1	5.1	4.9	4.9
Food, beverage, and tobacco products	0.4	0.5	0.2	0.3	-0.2	-0.2	-0.4	-0.3
Textile mills and textile product mills	0.3	0.3	-0.4	-0.4	4.5	4.5	3.7	3.7
Apparel and leather and allied products	-0.3	-0.3	-0.8	-0.8	7.2	7.2	6.5	6.5
Paper products, printing and related support activities	1.1	1.1	0.5	0.5	2.9	3.0	2.6	2.6
Petroleum and coal products	-6.2	-5.4	-5.9	-4.9	1.1	1.2	3.2	3.3
Chemical products	0.3	0.3	-0.4	-0.4	1.3	1.4	0.8	0.9
Plastics and rubber products	-0.4	-0.4	-0.7	-0.7	1.2	1.2	0.7	0.7
Wholesale trade	1.5	1.5	1.5	1.6	1.4	1.4	1.3	1.3
Retail trade	1.3	1.4	1.4	1.5	1.1	1.1	0.9	0.9
Transportation and warehousing	0.0	0.1	0.1	0.2	2.1	2.0	2.0	1.9
Information	1.3	1.4	0.9	1.0	5.4	5.5	4.9	5.0
FIRE, management of companies and enterprises	0.9	1.0	0.6	0.8	0.8	0.8	0.3	0.4
Professional, scientific, and technical services	-0.1	-0.1	-0.2	-0.2	0.0	0.0	-0.1	0.0
Administrative and waste management	-1.3	-1.2	-0.5	-0.5	2.1	2.1	2.0	2.1
Education and health care and social assistance	-0.6	-0.6	-0.5	-0.4	-1.0	-1.0	-1.0	-0.9
Arts, entertainment, and recreation	-1.6	-1.5	-1.6	-1.6	-0.4	-0.3	-0.5	-0.4
Accommodation and food services	-0.3	-0.3	-0.2	-0.2	0.0	0.0	-0.1	0.0
Other services (except public admin)	0.3	0.3	0.5	0.6	-2.7	-2.7	-2.8	-2.8
Correlations by Approach								
Ind1: StatCan depreciation, equal nominal rate of return	1.000	0.999	0.987	0.981	1.000	1.000	0.994	0.994
Ind2: StatCan depreciation, equal real rate of return		1.000	0.986	0.984		1.000	0.994	0.994
Ind3: BEA depreciation, equal nominal rate of return			1.000	0.997			1.000	1.000
Ind4: BEA depreciation, equal real rate of return				1.000				1.000

Table A4

Source of Labour Productivity Growth in the Canadian Business Sector

	Labour Productivity Growth (average annual growth rate, per cent)	Contributions (percentage points)				
		Labour Quality Growth	Structure Capital Intensity Growth	ICT Capital Intensity Growth	Non-ICT Capital Intensity Growth	MFP Growth
			1987-2010			
Bottom-up Approach						
Bus1	1.02	0.05	0.14	0.48	0.19	0.17
Bus2	1.02	0.05	0.14	0.45	0.17	0.21
Bus3	1.02	0.05	0.21	0.44	0.18	0.15
Bus4	1.02	0.05	0.21	0.40	0.16	0.21
Top-down Approach						
Bus5	0.98	0.25	0.12	0.47	0.17	-0.03
Bus6	0.98	0.25	0.13	0.43	0.15	0.01
Bus7	0.98	0.25	0.18	0.43	0.15	-0.03
Bus8	0.98	0.25	0.19	0.39	0.13	0.02
			1987-2000			
Bottom-up Approach						
Bus1	1.25	0.05	0.02	0.57	0.17	0.44
Bus2	1.25	0.05	0.03	0.53	0.16	0.48
Bus3	1.25	0.05	0.10	0.51	0.16	0.43
Bus4	1.25	0.05	0.10	0.46	0.15	0.49
Top-down Approach						
Bus5	1.25	0.32	-0.01	0.54	0.13	0.27
Bus6	1.25	0.32	0.00	0.50	0.11	0.32
Bus7	1.25	0.32	0.08	0.49	0.12	0.24
Bus8	1.25	0.32	0.08	0.44	0.10	0.31
			2000-2010			
Bottom-up Approach						
Bus1	0.72	0.04	0.30	0.37	0.20	-0.19
Bus2	0.72	0.04	0.30	0.34	0.18	-0.14
Bus3	0.72	0.04	0.36	0.35	0.20	-0.23
Bus4	0.72	0.04	0.36	0.31	0.17	-0.16
Top-down Approach						
Bus5	0.62	0.17	0.29	0.37	0.21	-0.42
Bus6	0.62	0.17	0.30	0.34	0.20	-0.39
Bus7	0.62	0.17	0.32	0.34	0.19	-0.40
Bus8	0.62	0.17	0.32	0.31	0.17	-0.35

Note: Labour productivity is defined as real value added per hour worked.

Table A5
Source of Labour Productivity Growth in the U.S. Business Sector

	Labour Productivity Growth (average annual growth rate, per cent)	Contributions (percentage points)				
		Labour Quality Growth	Structure Capital Intensity Growth	ICT Capital Intensity Growth	Non-ICT Capital Intensity Growth	MFP Growth
1987-2010						
Bottom-up Approach						
Bus1	1.95	0.01	0.04	0.82	0.29	0.78
Bus2	1.95	0.01	0.04	0.76	0.28	0.85
Bus3	1.95	0.01	0.20	0.75	0.28	0.70
Bus4	1.95	0.01	0.21	0.68	0.28	0.77
Top-down Approach						
Bus5	2.14	0.23	0.07	0.77	0.23	0.83
Bus6	2.14	0.23	0.07	0.72	0.22	0.89
Bus7	2.14	0.23	0.17	0.71	0.21	0.81
Bus8	2.14	0.23	0.18	0.64	0.20	0.88
1987-2000						
Bottom-up Approach						
Bus1	1.81	-0.02	-0.05	1.04	0.26	0.60
Bus2	1.81	-0.02	-0.06	0.96	0.24	0.69
Bus3	1.81	-0.02	0.08	0.93	0.24	0.58
Bus4	1.81	-0.02	0.08	0.84	0.24	0.68
Top-down Approach						
Bus5	1.95	0.28	-0.06	0.99	0.18	0.56
Bus6	1.95	0.28	-0.06	0.92	0.18	0.64
Bus7	1.95	0.28	0.03	0.89	0.14	0.62
Bus8	1.95	0.28	0.03	0.80	0.14	0.71
2000-2010						
Bottom-up Approach						
Bus1	2.11	0.05	0.17	0.53	0.34	1.03
Bus2	2.11	0.05	0.17	0.50	0.33	1.05
Bus3	2.11	0.05	0.35	0.51	0.34	0.86
Bus4	2.11	0.05	0.37	0.47	0.33	0.89
Top-down Approach						
Bus5	2.39	0.18	0.23	0.49	0.30	1.18
Bus6	2.39	0.18	0.24	0.47	0.28	1.21
Bus7	2.39	0.18	0.36	0.48	0.30	1.06
Bus8	2.39	0.18	0.38	0.44	0.28	1.10

Note: Labour productivity is defined as real value added per hour worked.

Can the Canada-U.S. ICT Investment Gap be a Measurement Issue?

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ABSTRACT

In 2011, business sector investment per worker in information and communications technology (ICT) in Canada was only 57.8 per cent of the U.S. level, indicating an ICT investment per worker gap of 42.2 percentage points. Numerous explanations have been advanced to explain this gap, one of which is that the ICT investment data from Statistics Canada and the Bureau of Economic Analysis are not strictly comparable. We compare the methodology used to measure ICT investment in Canada and the United States and find that issues related to measurement account for approximately 4 percentage points (10 per cent) of the gap. The gap is concentrated in the software component of ICT investment (90 per cent) and in a small number of ICT-intensive industries, in particular information and cultural industries. The article concludes that the Canada-U.S. ICT investment per worker gap is largely the result of industry-specific factors that affect software investment.

IN 2011, BUSINESS SECTOR INVESTMENT per worker in information and communications technology (ICT) in Canada was only 57.8 per cent of the U.S. level. Software investment, the largest component of ICT investment in both countries, was only 39.8 per cent of the U.S. level. These observations are a part of a persistent phenomenon identified in a series of studies conducted by the Centre for the Study of Living Standards (CSLS) showing that ICT investment per worker in Canada is significantly below the U.S. level.[2] This low level of ICT investment per worker is troubling, as investment—and ICT investment in particular—increases labour productivity, an important determinant of potential economic growth and a measure by which the United States has also consistently outperformed Canada over the last decade.

Several factors have been posited as the source of the gap in ICT investment per worker, including differences in economic and industrial structure; relative costs and prices; attitudes and culture; framework variables such as education, taxes, and competitiveness; and, finally, measurement error in the level of investment in either or both countries. The primary focus of this article is to explore the extent to which differences in measurement methodology contribute to the observed gap in ICT investment per

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2 For detailed discussions of how the ICT investment per worker gap has evolved over time and some discussion of the factors underlying the gap, see CSLS (2005); Sharpe (2006); Sharpe and Arsenault (2008a); Sharpe and Arsenault (2008b); Sharpe and de Avillez (2010); Sharpe and Moeller (2011); and Sharpe and Andrews (2012).

worker, in order to better inform policymakers concerned about the strength of investment in Canada. An understanding of the causes of the Canada-U.S. ICT investment per worker gap is essential for the development of policies to reduce the gap.

This article is organized as follows. The first section briefly describes trends in the Canada-U.S. ICT investment gap over time. The second section provides several decompositions of the ICT investment per worker gap, identifying which components of ICT investment and which industries make the largest contributions to the gap. The third section highlights non-measurement factors that contribute to the gap. The fourth section focuses on comparisons of different elements of the methodologies used to construct the ICT investment time series in Canada and the United States. It identifies differences in definitions, and provides estimates for the degree to which the gap is over- or under-estimated due to measurement error. The fifth and final section concludes.[3]

The Canada-U.S. ICT Investment per Worker Gap

The Canada-U.S. ICT investment per worker gap has fluctuated over time, but has not changed substantially over the 1987-2011 period.[4] Business sector ICT investment per worker was 57.8 per cent of the U.S. level in 2011; in 1987, we observed a similar relative level of 59.3 per cent. In the intervening years, it has been as high as 68.0 per cent of the U.S. level in 1991 and as low as 53.9 per cent in 2009. While the overall ICT investment per worker gap in 2011 is similar to the gap in 1987, the gap by component has shifted dramatically. In 1987, the gap for all three components was around 40 percentage points, but in 2011, software investment per worker in Canada was only 39.8 per cent of the U.S. level, communications equipment investment per worker was 72.9 per cent, and computer investment per worker was 108.8 per cent. Our goal in this section is to highlight important features of the Canada-U.S. ICT investment per worker gap, such as the extent to which the gap is now significantly greater in software investment than in the two other ICT components.

The Canada-U.S. ICT Investment per Worker Gap

Our key indicator for comparing Canada's performance in ICT investment to that of the United States is the Canada-U.S. relative level of ICT investment per worker, which is calculated as the ratio between nominal business sector ICT investment per worker in Canada and in the United States. Following the generally accepted OECD definition of information and communications technology, ICT investment is defined as investment in computers, software, and telecommunications equipment. To convert ICT investment per worker in Canada to U.S. dollars, we use purchasing power parity (PPP) estimates, which take into account differences in the prices of goods and services between the two countris.[5] The Canada-U.S. ICT investment per worker gap is simply 100 minus the Canada-U.S. relative level of ICT investment per worker.[6]

3 This article is accompanied by a set of Appendix Tables that provide more details on the estimates. The Appendix Tables are available on the CSLS website at www.csls.ca/res_reports.asp. Additionally, the CSLS maintains a database on ICT investment and capital stock by industry in Canada and the United States based on publicly-available data from Statistics Canada and the U.S. Bureau of Economic Analysis. This database is publicly available at www.csls.ca/data/ict.asp.

4 For a detailed report on the state of the Canada-U.S. ICT investment per worker gap in 2011, see Capeluck (2013).

As noted earlier, the Canada-U.S. ICT investment per worker gap in 1987 was very similar across all three components, but this is no longer the case (Table 1). Since 1987, software investment per worker has declined significantly relative to the United States, from a high of 70.3 per cent of the U.S. level in 1994, to 39.8 per cent of the U.S. level in 2011. At the same time, computer investment per worker increased from 62.6 per cent in 1987 to 108.8 per cent of the U.S. level by 2011. Investment in communications equipment has also increased, from 55.9 per cent of the U.S. level in 1987 to 72.9 per cent of the U.S. level in 2011. Meanwhile, total ICT investment per worker has generally been close to 60.0 per cent during the entire period. The divergence in the ICT investment per worker gap by component begins in the mid-1990s, and continues to 2011. This is a very dramatic shift in the composition of the ICT investment per worker gap, from a relatively uniform gap across all components, to no gap at all in computers, an extremely large gap in software, and a substantial but smaller gap in communications equipment.

Table 1

Business Sector ICT Investment per Worker in Canada (PPP adjusted) Relative to the United States, 1987 and 2000-2011

(per cent of U.S. investment)

	Total ICT	Computers	Communications	Software
1987	59.3	62.6	55.9	59.6
...				
2000	52.2	68.9	54.2	41.7
2001	54.9	67.8	62.8	44.3
2002	56.6	74.5	71.4	42.2
2003	56.5	81.9	68.0	41.6
2004	59.9	93.6	66.9	44.3
2005	64.7	105.5	68.5	49.0
2006	65.2	112.6	65.8	48.0
2007	63.1	104.1	53.9	52.6
2008	62.5	103.7	62.7	49.1
2009	54.0	101.7	65.7	37.3
2010	54.7	109.8	61.7	37.6
2011	57.8	108.8	72.9	39.8
Absolute Change				
1987-2011	1.5	-42.6	-17.0	19.8

Source: Appendix Table 1c.

Note: Data for 1988-1999 available in Appendix Table 1c.

Another key trend is that the level of ICT investment per worker in Canada relative to that of the United States grew significantly faster in the 2000-2011 period than it did in the 1987-2000 period. The relative level peaked in 2006 at 65.24 per cent, falling precipitously in 2009 during the recession. Since then, the level of ICT investment per worker in Canada has increased relative to the United States (Sharpe and de Avillez, 2010; Sharpe and Andrews, 2012; Capeluck, 2013). Chart 1 illustrates that the gap in total ICT investment per worker has fluctuated significantly over time but still remains relatively close to its level in 1987; it also shows the dramatic evolution of the composition of the gap by component for the 1987-2011 period.

It is interesting to note that the Canada-U.S. ICT investment per worker gap appears to be uniquely a business sector phenomenon. In the non-business sector, ICT investment per worker in the two countries was approximately the same in 2007.[7]

5 Ideally, the PPP estimates used to calculate the Canada-U.S. ICT investment per worker gap would refer specifically to ICT investment. Unfortunately, such estimates do not exist. The closest alternative is the machinery and equipment (M&E) PPP calculated by Statistics Canada, which is the PPP used in this article to estimate the Canada-U.S. ICT investment per worker gap. In general, ICT can be seen as a subcategory of M&E. As such, using the M&E PPP instead of the ICT PPP (which is unavailable) provides a reasonable, albeit imperfect alternative to the more precise measure of the ICT gap.

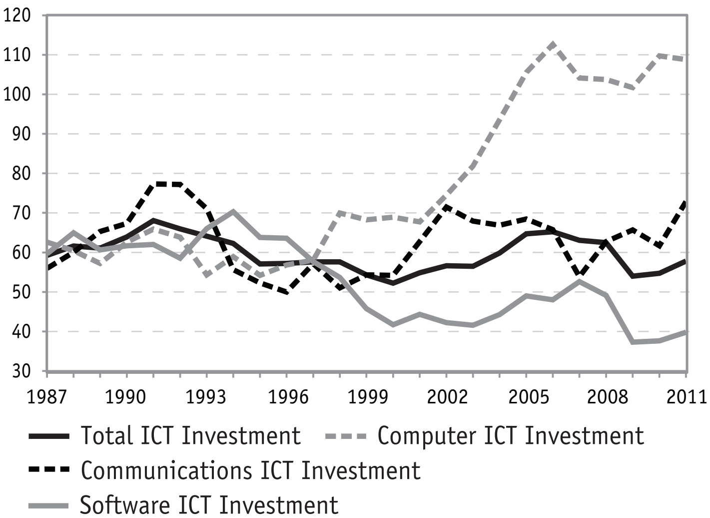
6 There are, of course, ways to compare ICT investment in Canada and the United States without using labour input, and these measures also point to a large Canada-U.S. ICT investment gap.

7 This is the only year for which OECD data on ICT investment allow us to perform this calculation. U.S. data do not uniquely identify non-business ICT investment in any year.

Chart 1

ICT Investment per Worker in Canada Relative to the United States, Business Sector, 1987-2011

(per cent)

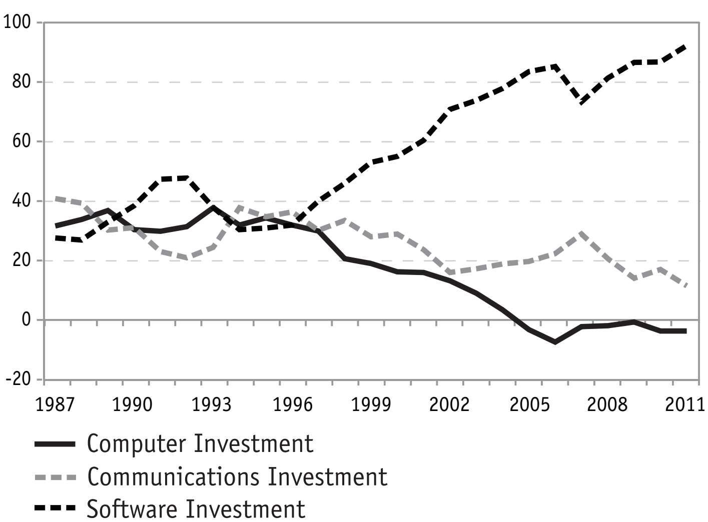


Source: Appendix Tables 1a-c, 2a-c, 3a

Chart 2

Relative Contribution to the Total ICT Investment per Worker Gap by Component, 1987-2011

(per cent)



Source: Appendix Tables 1a-c, 2a-c, 3a

Decomposition of the Canada-U.S. ICT Investment Gap by Component, Industry, and Province

The ICT investment per worker gap can be decomposed in three ways. First, it can be decomposed into the components of ICT: computers, software, and communications equipment. Second, it can be decomposed by industry, and by component within industry. Third, for Canada, ICT investment per worker can be decomposed by province, although it cannot be decomposed by state for the United States. Investment per worker in each province can be compared to investment per worker in the United States, but because U.S. ICT investment data are not available by state or region, we can only determine whether a particular province has a larger or smaller gap than the national gap. Decomposing the ICT investment per worker gap will direct our investigation of measurement issues to the most important sources of the gap.

Decomposition by Component

Software investment is the largest component of ICT investment, accounting for 48.5 per cent and 64.5 per cent of of total ICT investment in Canada and in the United States, respectively, in 2011. The difference in software investment per worker accounted for 92.2 per cent of the gap, meaning that software investment was almost wholly responsible for Canada's low level of ICT investment per worker relative to the United States (Table 2). This observation motivates our investigation in this article of the methods used to measure different types of software investment.

In 1987, the relative contribution of each component to the gap was very similar. Since 1995, there has been a consistent trend towards the concentration of the gap in the software component (Chart 2).

Table 2

Decomposition of the Canada-U.S. ICT Investment Gap by Component, Canada and the United States, Business Sector, 2011

	Canada (U.S. dollars)	United States (U.S. dollar)	Canada Relative to the United States (per cent)	Difference (U.S. dollars)	Relative Contribution to gap (per cent)
	A	B	C = A/B	D = A - B	E = D/-1658
Computers	752	691	108.8	61	-3.7
Software	1,011	2,540	39.8	-1,529	92.2
Communications	510	700	72.9	-190	11.5
Total	2,273	3,931	60.1	-1,658	100.0

Source: Calculations based on CSLS ICT Investment Database Tables S1-4.

Given the role of software investment in the total Canada-U.S. ICT investment per worker gap, it is important to break down software investment by type of software. Statistics Canada's Input-Ouput tables break down software investment into three components: pre-packaged, own-account, and custom-designed software.

In 2009 (the last year for which data were available), pre-packaged software represented less than 20 per cent of total software investment in Canada, while in the United States it accounted for almost 30 per cent of software investment. The importance of own-account software investment was also smaller in Canada than it was in the United States (34.0 per cent of total software investment vs. 38.5 per cent, respectively). Over 45 per cent of software investment in Canada was in the form of custom-designed software (vs. 32 per cent in the United States).

Table 3 provides a detailed decomposition of the Canada-U.S. ICT investment gap in 2009, taking into account the different types of software investment. Based on these data, own-account software investment was responsible for fully 35.1 per cent on the total ICT investment per worker gap in 2009. Pre-packaged software makes a slightly smaller contribution of 31.2 per cent to the gap in 2009. At 10.5 per cent, the contribution of custom software to the gap is significantly smaller than the contribution of the two other software components.

Decomposition by Industry of Total ICT Investment per Worker Gap

The ICT investment per worker gap can be decomposed by industry in Canada and the United States for a direct comparison between industries.[8] Furthermore, we can also compare the gap in each industry by ICT components to determine whether the large gap in software investment per worker is a persistent trend across industries, or whether it is concentrated in particular industries.

Due to the lack of availability of 2011 estimates of communications investment for many industries, we perform this decomposition for 2009. The industries included in this decomposition comprise 82.0 per cent of business sector employment in the United States.

As Table 4 shows, information and cultural industries constitute the largest contributor to the gap, followed by finance and insurance and professional, scientific, and technical services. This industry breakdown of the Canada-U.S. ICT investment per worker gap also highlights a number of other important facts:

8 Statistics Canada's Fixed Capital Flows and Stocks program defines the business sector as all industries excluding health care and social assistance, educational services, and public administration. Consequently, investment by private establishments in health care is not captured in these data.

Table 3

Relative Contribution to the Canada-U.S. ICT Investment per Worker Gap of Software Investment Components, 2009

	Canada Investment per Worker (PPP adjusted)	U.S. Investment per Worker	Canada Relative to U.S.	Difference	Relative Contribution to the Software Investment per Worker Gap	Relative Contribution to the Total ICT Investment per Worker Gap
	A	B	C = A/B	D = A - B	E = D/-1473	F = E/-1700
Software	875	2,348	37.3	-1,473	100	86.6
Own-account Software	323	919	35.1	-597	40.5	35.1
Custom	568	746	76.10	-178	12.1	10.5
Pre-packaged	166	697	23.9	-531	36.0	31.2
Computers	662	651	101.7	11	n.a.	-0.7
Telecommunications Equipment	480	694	69.2	-214	n.a.	12.6
Total ICT	1,993	3,693	54.0	-1,700	n.a.	100.0

Source: Appendix Table 3a.

Note: The estimates of own-account software, custom software, and pre-packaged software come from the I/O Tables, which currently produce an estimate of total software investment somewhat greater than does the Fixed Capital Flows and Stocks Table, the source of the other estimates of ICT investment in this table. As a result, the relative contributions for software will sum to less than 100 per cent.

- There is a massive variation in ICT investment per worker at the two-digit NAICS level for both Canada and the United States. Focusing our attention on Canada, the industry with the lowest level of ICT investment per worker in 2009 was agriculture, forestry, fishing and hunting ($311), while the industry with the highest level was information and cultural industries ($16,530).
- For two-digit NAICS industries, there is a large variation in the Canada-U.S. relative levels of ICT investment per worker, which ranged from 22.8 per cent in mining and oil and gas extraction in 2009 and 279.4 per cent in the case of professional, scientific and technical services. In two industries, Canada's ICT investment per worker levels were more than double of the U.S. levels.
- Although the Canada-U.S. relative level of ICT investment per worker for the business sector was 54.0 per cent in 2009, only five industries had relative levels below or at the business sector average. Two of these industries were, however, ICT-intensive industries: information and cultural industries, where Canada's ICT investment per worker level relative to the U.S. was 53.8 per cent; and professional, scientific and technical services where the Canada-U.S. relative was only 26.5 per cent.

Proximate Causes of the Canada-U.S. ICT Investment per Worker Gap

There are important differences between the Canadian and U.S. economies that have led, directly or indirectly, to the greater level of ICT investment per worker in the United States. These differences are measurable and their effect on the gap, holding all else constant, is also measurable. We identify two such features of the two economies, labour productivity and industrial structure, and provide estimates of their effect on the gap.

Labour Productivity

Labour productivity is an important determinant of income per capita, which in turn

Table 4
Decomposition of Total ICT Investment per Worker Gap by Business Sector Industry, 2009

	ICT Investment per Worker					
	Canada (current U.S. dollars)	United States (current U.S. dollars)	Canada Relative to the United States (per cent)	Absolute Difference	U.S. Employment Shares (per cent)	Weighted Contribution to the Total ICT Gap (per cent)
	A	B	C = A/B	D = A - B	E	F = E x D/-1700
Business Sector	1,993	3,693	54.0	-1,700	100.0	100.0
Agriculture Forestry Fishing and Hunting	311	192	162.1	119	1.9	-0.1
Mining and Oil and Gas Extraction	1,240	5,430	22.8	-4,190	0.7	1.6
Manufacturing	1,167	2,580	45.2	-1,413	13.0	10.8
Wholesale Trade	2,576	5,037	51.1	-2,461	3.5	5.0
Retail Trade	729	881	82.8	-151	14.5	1.3
Information and Cultural Industries	16,530	30,742	53.8	-14,212	3.0	24.8
Finance and Insurance	6,290	10,168	61.9	-3,878	6.2	14.2
Real Estate Rental and Leasing	6,124	2,192	279.4	3,933	2.6	-5.9
Professional Scientific and Technical Services	1,416	5,340	26.5	-3,924	4.9	11.3
Educational Services	0	529	0	-529	12.1	3.8
Health Care and Social Assistance	0	610	0	-610	17.0	6.1
Arts Entertainment and Recreation	915	450	203.3	465	2.8	-0.8
Total allocated					82.0	70.8
Unallocated (calculated as a residual)					28.0	29.2

Note: Weighted relative contribution is the difference in each industry relative to the business sector difference in total ICT investment per worker, weighted by the employment shares of that industry in the United States. Industries for which data were not available for both countries are omitted. Total allocated industries refer to the sum of the weighted relative contribution; unallocated industries are calculated as the residual. Investment in health care and educational services in Canada are treated as zero for the purpose of this decomposition, because the Fixed Capital Flows and Stocks program in Canada defines this investment as not occurring in the business sector.

affects ICT investment per worker. In this sense, differences in labour productivity explain part of the Canada-U.S. ICT investment per worker gap. Holding constant ICT investment as a share of GDP, a country with higher labour productivity (defined here as PPP-adjusted nominal GDP per worker)[9] will have a higher level of ICT investment per worker compared to a country with a lower labour productivity level.

In fact, according to CSLS calculations, the Canada-U.S. ICT investment per worker gap would have been 12.6 percentage points lower in 2011 if the two countries had had the same labour productivity level.[10] This represents slightly less than a third of the ICT gap of 42.2 per cent in 2011, in line with the average contribution of labour productivity to the ICT gap throughout the 1987-2011 period. The higher ICT share of GDP in the United States

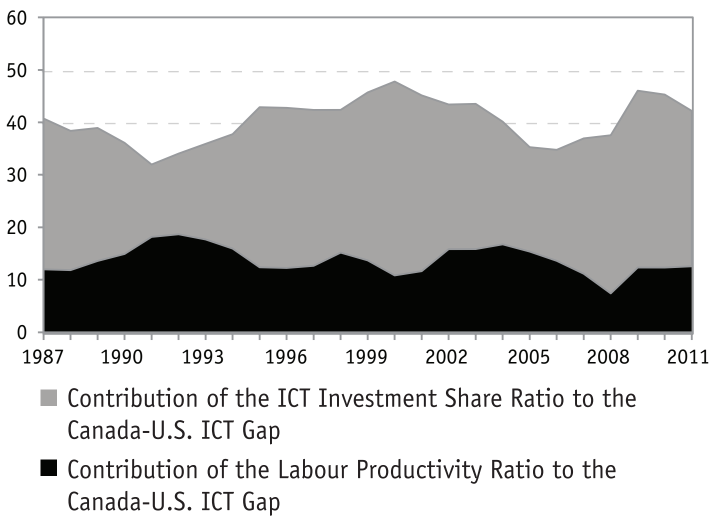
9 The reader should keep in mind that labour productivity levels are sometimes defined in real terms—either as real GDP per hour worked or as real GDP per worker. In this section, however, we defined it in nominal terms because we are interested in the *level* of nominal income being generated per worker.

10 For details, See Rai and Sharpe (2013).

Chart 3

Labour Productivity and ICT Share Contributions to the Canada-U.S. ICT Investment per Worker Gap, 1987-2011

(percentage points)



Source: CSLS calculations based on Appendix Tables.

accounted for the remaining two-thirds of the Canada-U.S. ICT gap. Chart 3 plots the contribution of each of these two factors over the past 25 years. Despite some significant fluctuations over the period (especially in the early 1990s), the contribution of labour productivity differentials to the Canada-U.S. ICT gap has remained fairly stable over time.

It is important to highlight that the decomposition of the Canada-U.S. ICT investment per worker gap into these two factors offers only a *proximate* explanation of the gap. After all, it does not answer the question as to what exactly is causing labour productivity differences between the two countries or why Canada invests less in ICT (as a share of GDP) than the United States. It is also true that the difference in labour productivity is not entirely an exogenous phenomenon. It may well be the case that Canada's lower ICT investment per worker partially explains its lower labour productivity when compared to the United States, rather than the reverse. Nonetheless, the above decomposition is valuable in its own right and can be used to inform the direction of future research.

Industrial Structure

Differences between the industrial structures in Canada and in the United States can, potentially, explain part of the Canada-U.S. ICT investment per worker gap. At the business sector level, ICT investment per worker is simply the weighted average of ICT investment per worker at the *industry level*, where the weights are employment shares. If, compared to Canada, the U.S. economy favours ICT-intensive industries, i.e. industries with above-average levels of ICT investment per worker increase the gap compared to a baseline scenario where both countries have the same industrial structure.

To estimate the effect of industrial structure on the Canada-U.S. ICT investment per worker gap, the CSLS calculated how much Canada's business sector ICT investment per worker would be if Canada's employment shares were equal to those of the United States. The two countries have a fairly similar employment share structure at the business sector level. In both countries, the largest sector was retail trade, which accounted for 15.6 per cent of employment in Canada's business sector versus 15.7 per cent in the United States. Manufacturing came close second, representing 13.5 per cent of the business sector in Canada and 14.2 per cent in the United States. This was followed by professional, scientific and technical services (10.1 per cent in Canada versus 9.4 per cent in the United States); construction (9.7 per cent versus 8.9 per cent); and accommodation and food services (8.4 per cent versus 9.7 per cent). Overall, these five industries accounted for approximately 57-58 per cent of business sector employment in both countries.

Table 5

Canada-U.S. Relative Level of ICT Investment per Worker, Actual x Simulated, 2011

(PPP-adjusted U.S. dollars, U.S. employment share weights)

		Variable	Unit	Value
Canada	A	ICT Investment per Worker, actual	(dollars)	2,525
	B	ICT Investment per Worker, simulated	(dollars)	2,629
	C=B-A	Difference between Simulated and Actual	(dollars)	104
	D=(C/A)*100		(per cent)	4.1
	E	Canada-U.S. Purchasing Power Parity		0.90
	F=A*E	ICT Investment per Worker, actual	(PPP-adjusted U.S. dollars)	2,273
	G=B*E	ICT Investment per Worker, simulated	(PPP-adjusted U.S. dollars)	2,366
United States	H	ICT Investment per Worker	(U.S. dollars)	3,931
Canada as a Share of the United States	I=(F/H)*100	ICT Investment per Worker, actual	(per cent)	57.8
	J=(G/H)*100	ICT Investment per Worker, simulated	(per cent)	60.2
	M=K-L	Difference between Simulated and Actual	(percentage points)	2.4

Source: CSLS calculations based on data from the CSLS ICT database.

Notes: For details on how the simulated estimates were calculated, refer to Appendix Tables.

Table 5 presents the simulated level of ICT investment per worker in Canada using U.S. employment shares as weights, and compares it to the actual level in 2011. Using U.S. weights, business sector ICT investment per worker in Canada was $2,629, 4.1 per cent higher than the actual level of $2,525. Converting these figures to PPP-adjusted U.S. dollars, we find that if Canada had the U.S. employment shares, its business sector ICT investment per worker level would have been 60.2 per cent of the U.S. level, while its *actual* level was only 57.8 per cent that of the United States, a difference of 2.4 percentage points.

Despite many similarities, there are small but significant differences in the way the two countries allocate labour. In Canada, for instance, mining and oil and gas extraction in Canada represents 2.1 per cent of business sector employment versus 0.8 per cent in the United States, a difference of 1.3 percentage points. Accommodation and food services, on the other hand, represents a higher employment share in the United States than in Canada (9.7 per cent versus 8.4 per cent, respectively), again a difference of 1.3 percentage points.

Table 6 shows how each industry contributed to the overall effect of industrial structure on the Canada-U.S. ICT investment per worker gap in 2011. Recall from Table 13 that the simulated ICT investment per worker level (using U.S. weights) in 2011 was greater than the actual level by $104. The industries that contributed the most to this difference were: finance and insurance ($46); management of companies and enterprises ($45);[11] and information and cultural industries ($38). Note that these three industries had above-average ICT investment per worker levels, which magnified their overall contribution to the total industrial structure

Table 6
Industry Contributions to the Difference between Actual and Simulated ICT Investment per Worker Level in Canada, 2011

	Employment Shares			ICT Investment per Worker		Industry Contributions to Difference Between Simulated and Actual	
	Canada	United States	Canada-U.S.	Level, Actual	Compared to Business Sector		
	(per cent)			(dollars)		(dollars)	(per cent)
	A	B	C=B-A	D	E	F=(C/100)*D	$G=(F_{ind}/F_{tot})*100$
Business Sector	100.0	100.0	0.0	2,525	=	104	100.0
Agriculture	2.9	2.2	-0.6	360*	<	-2	-2.2
Mining and Oil	2.1	0.8	-1.3	2,398*	<	-31	-29.4
Utilities	1.1	1.2	0.2	13,214*	>	20	19.6
Construction	9.7	8.9	-0.8	255*	<	-2	-1.8
Manufacturing	13.5	14.2	0.7	1,882	<	12	12.0
Wholesale Trade	4.9	3.8	-1.1	3,900*	>	-43	-41.5
Retail Trade	15.6	15.7	0.1	1,026*	<	1	1.0
Transportation	6.5	5.9	-0.6	2,467*	<	-14	-13.9
Information Industries	2.9	3.1	0.2	19,434	>	38	36.8
Finance and Insurance	5.8	6.5	0.7	6,439	>	46	44.5
Real Estate	2.5	2.7	0.2	5,888*	>	14	14.0
Professional Services	10.1	9.4	-0.7	1,931	<	-13	-13.0
MCE	0.0	0.2	0.2	25,128*	>	45	42.9
ASWMRS	5.1	6.1	0.9	1,626*	<	15	14.9
Arts	3.0	2.9	-0.1	1,369*	<	-1	-1.0
Accommodation	8.4	9.7	1.3	355*	<	5	4.4
Other Services	5.8	6.6	0.8	1,615*	<	13	12.7

* These figures are CSLS estimates constructed using data from two different Statistics Canada series (Fixed Capital Flows and Stocks, CANSIM Table 031-0003, and Canadian Productivity Accounts, CANSIM Table 383-0025). For details on how these estimates were calculated, refer to appendix tables.

Source: CSLS calculations based on the CSLS ICT database.

Notes: 1) ASWMRS – Administrative and support, waste management and remediation services; MCE – Management of companies and enterprises; 2) Business sector is defined here as total economy minus public administration; health care and social assistance; and education.

effect. Conversely, the industries that contributed the most to *closing* the difference between actual and simulated levels all had below-average ICT investment per worker levels: wholesale trade (-$43); mining and oil and gas extraction (-$31); and transportation and warehousing (-$14). Overall, ten out of the seventeen industries played a role in *increasing* the difference between actual and simulated levels of ICT investment per worker.

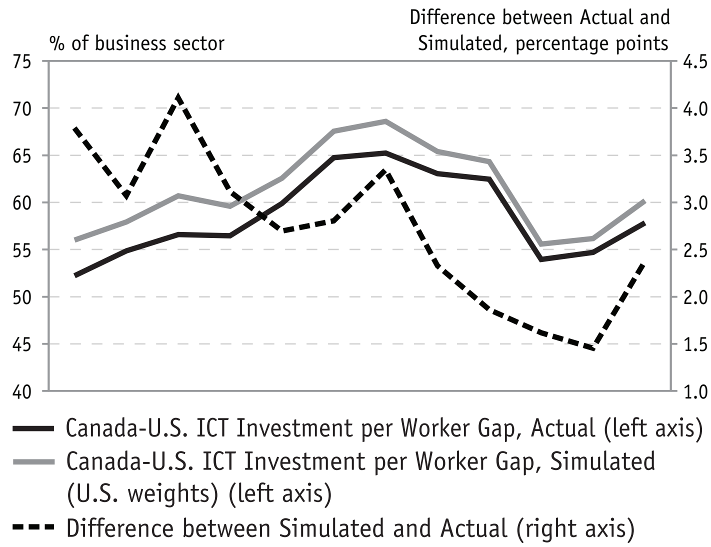
Although the impact of industrial structure on the Canada-U.S. ICT investment per worker gap was still significant, it is interesting to note that its magnitude declined from its pre-2007 levels. Chart 4 plots Canada's ICT investment per worker level relative to that of the United States from 2000 to 2011. The difference between the two series reached a peak in 2002, when the Canada-U.S. ICT investment per worker relative was 56.6 per cent versus the sim-

11 This significant contribution of management of companies and enterprises (MCE) is caused by an allocation issue. MCE investment represents investment made by head offices. In reality, a significant part of that investment will be assigned to activities other than MCE, which means that MCE investment is actually investment in other industries.

ulated value of 60.7 per cent, a difference of 4.1 percentage points. There was an increase in the difference between the two series in 2011, but it is still too early to tell if this represents a change in trend or whether it simply reflects temporary fluctuations.

The key take away from this simulation exercise is that Canada's somewhat lower employment share in ICT-intensive industries caused the Canada-U.S. ICT investment per worker gap to be 2.4 percentage points higher than it would have been if Canada had had the same industrial structure as the United States; this is equal to 5 per cent of the gap. A small number of industries contributed disproportionately to this effect—finance and insurance and information and cultural industries, in particular. In the case of the latter, even though Canada's employment share was only 0.2 percentage points below that of the United States, the extremely high level of ICT investment per worker amplified the effect that differences in industrial structure had on the Canada-U.S. ICT investment gap.

Chart 4
Canada-U.S. ICT Investment per Worker Relative, Actual x Simulated, 2000-2011
(PPP-adjusted U.S. dollars)



Source: CSLS calculations based on the CSLS ICT database.

Contribution of Differences in Measurement Methodology to the Canada-U.S. ICT Investment per Worker Gap

Our analysis in the preceding section has explained a significant portion of the ICT investment per worker gap, but approximately 65 per cent of the gap still remains unexplained. Of the factors that we reviewed, we explain approximately one-fifth of the gap through quantifiable differences between Canada and the United States, particularly greater U.S. labour productivity (12 percentage points or 30 per cent) and differences in industrial structure (2.5 percentage points or 5 per cent). Because much of the gap remains unexplained, we now turn our attention to comparing measurement methodologies in Canada and the United States to determine to what degree the estimates we use to compute the gap are comparable. We look both for inconsistencies in what the two countries are estimating, and sources of error in how they produce their estimates that could affect our estimate of the ICT investment per worker gap.

This section proceeds as follows. First, we begin with a quick overview of the main data sources used to calculate the Canada-U.S. ICT investment per worker gap. Next, we provide a discussion of definitions of ICT commodities, business sector investment in ICT, and business sector employment. We include a discussion based on the reporting guides of the surveys used to collect data on ICT investment in both countries, and discuss differences in the definitions of business sector employment and investment. We also discuss differences in the composition or size of the business sector in Canada and the United States, which is a measurement issue for the purposes of comparing business sector ICT investment per worker. Second, we review the design of the surveys used in the two countries and compare sample methodology and coverage, response rates, and coefficients of variation. Finally, we discuss in great detail the estimation of own-account software, i.e. software developed by the employees of a firm for internal use, and compare the estimates of own-account software in the two countries. Own-account software is the most difficult component of software to estimate, and as software investment accounted for 92.2 per cent of the ICT investment per worker gap in 2011, this is an important area of research.

Data Sources

For both Canada and the United States, comparing ICT investment per worker requires estimates of: (a) business sector ICT investment; (b) employment in the business sector, and by industry; and (c) purchasing power parity (PPP).

For Canada, our main source of ICT investment estimates is Statistics Canada's Fixed Capital Flows and Stocks (FCFS) program,[12] which are in turn constructed using estimates from the Capital and Repair Expenditure Survey (CES). For the United States, ICT investment estimates come from the Bureau of Economic Analysis (BEA), more especificaly the BEA's Fixed Asset Accounts. These estimates are primarily constructed using data from the Annual Capital and Expenditure Survey (ACES) and the Information Communications Technology (ICT) Survey.

Employment estimates for Canada are obtained from Statistics Canada's Labour Force Survey (LFS), while for the United States they are obtained from the Current Population Survey (CPS). Finally, official PPP estimates are obtained from Statistics Canada.

Differences in Definitions

There are two sets of definitions that are important to our estimates of the business sector ICT investment per worker gap. First, there are the definitions of ICT components, that is, computers, communications equipment, and software. We examined the reporting guides accompanying the surveys used by statistical agencies in both countries to determine to what degree the definitions of these components differ, if at all. Second, the definition of the business sector used by Statistics Canada's FCFS program is important in the calculation of business sector ICT investment per worker, as it affects both investment and employment estimates.

ICT Component Definitions

In addition to a harmonized industry classification system (NAICS), Canada and the United States have harmonized definitions of trade commodities. However, the definitions of commodity classes for private fixed investment are not harmonized; the Bureau of Economic Analysis' (BEA) Fixed Asset Accounts and Statistics Canada's FCFS program report private non-residential fixed investment for asset types that do not follow exactly the same definition. It is therefore possible that the values reported for investment for a particular ICT asset type will not refer to the same groups of commodities in the two countries. We examined the definitions of the assets that comprise ICT in order to determine whether definitional differences pose a challenge for comparing ICT investment in Canada and the United States. Despite some ambiguities, we found no major definitional differences that would cause ICT estimates from Canada and the United States to not be comparable.

12 Additional ICT investment data for Canada are obtained from the Canadian Productivity Accounts (CPA) and the Input-Output (IO) Tables.

Business Sector Definitions

Our interest in ICT investment per worker has been confined to the business sector because business sector investment is an important determinant of productivity. In order for our estimates of the Canada-U.S. business sector ICT investment per worker gap to be accurate, it must be the case that the definition of the business sector in Canada and the United States is the same. Unfortunately, this is not the case—Statistics Canada's FCFS tables, our primary source of investment data for Canada, do not use the same definition of the business sector as the BEA Fixed Asset Accounts, our primary source of investment data for the United States. Rai and Sharpe (2013) show that this mismatch in definitions has most likely led to a understament of the gap.

Differences in Data Collection Methodologies

Our analysis of the investment surveys used in Canada and the United States did not find any significant differences in the surveys themselves that would affect our estimate of the gap. Rai and Sharpe (2013) discuss five elements of data collection: survey sample frame, sample size, sample stratification, quality control and analysis, and non-sampled entities. In regard to survey sample frame, all three surveys consist of a random sample drawn from the respective business registry. In both countries, the business registry covers approximately 97 per cent of all businesses. One important difference, however, is that in Canada, all government entities as well as private entities are included in the sample frame; in the United States, government estimates do not contain the same detail as private data. The government fixed assets data do not support as detailed a breakdown as the private fixed assets data, and do not allow for the identification of ICT investment. This is not a measurement issue for comparing the business sector in the two countries, but it does mean that it is not possible to produce comparable estimates of ICT investment for the total economy in Canada and the United States. This, in turn, means that our focus on the business sector is also necessary.

Regarding sample size, we did not expect to uncover anything unusual, and we did not. The sample size is larger in the United States, but both countries use samples in the tens of thousands of establishments, with more than enough respondents completing the long- and short-form variants of each survey. Our findings for stratification were similar; Statistics Canada uses an algorithm based on revenue to determine which strata are fully surveyed and which strata are sampled, while the Census Bureau also employs a revenue-based mechanism to assign establishments into strata. These algorithms are essentially the same.

Quality control and analysis methods were also similar in both countries. We conducted detailed interviews with individuals from Statistics Canada and the BEA to determine that similar efforts were being made at both agencies to ensure the reliability of survey data. Explicit measurement error was dealt with in the initial data collection phases using ratio estimators and other methods to identify reported values that were either out of bounds or inconsistent with previous estimates, and follow-up calls to respondents were routine in both agencies. Likewise, both agencies report a response rate in excess of 70 per cent.

Finally, we found that both agencies had several methods of dealing with the challenges posed by non-sampled entities. These entities would explicitly be excluded from Statistics Canada's estimates, which exclude very small establishments that cannot be sampled with certainty. Statistics Canada estimates the investment values for these entities using administrative data, including tax data.

Similarly, the BEA uses administrative data for non-employer establishments; where establishment-level data are not possible to estimate, the BEA uses activity-level data for any non-manufacturing establishment as a proxy. Overall, both agencies reported that this issue would only affect establishments comprising between 2.5 and 3.0 per cent of firm revenue, leading us to conclude that the impact of collection on the estimates is negligible.

Differences in Software Investment Measurement Methodology

Software investment was responsible for 92.2 per cent of the gap in 2011, and has been responsible for a similar share of the gap for much of the last decade. Furthermore, software is the most difficult component of ICT investment to accurately measure. Business accounting practices are generally inadequate for investment surveys to accurately capture software investment, and so software investment in Canada and the United States is estimated using indirect methods. In this section, we compare the indirect methods used by Statistics Canada and the Bureau of Economic Analysis to estimate investment in the three types of software.

Measurement of Pre-packaged Software

Investment per worker in pre-packaged software in Canada, which was just 26.4 per cent of the U.S. level, was responsible for 31.2 per cent of the total gap in business sector ICT investment per worker on its own in 2009 (the most recent year for which detailed data are available). We review the methodology used by Statistics Canada and the Bureau of Economic Analysis to estimate investment in pre-packaged software, and discuss any differences thereof.

Commodity-flow Methodology for Pre-packaged Software Investment

In Canada and the United States, estimates of software investment do not rely exclusively on the survey data from the CES, ACES, and ICT surveys we have previously discussed due to challenges in business accounting that make it difficult for businesses to report data in sufficient quality or detail. Instead, an indirect method of estimating pre-packaged software investment is used. In Canada, these estimates are constructed by Statistics Canada's Canadian System of National Accounts (CSNA) and then used by FCFS to produce estimates of final investment in software. In the United States, the three divisions within the BEA are involved in this estimation.

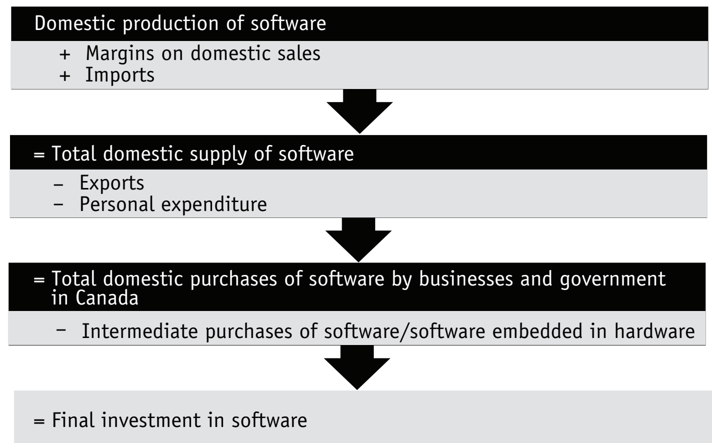
The CSNA uses a commodity-flow method to estimate pre-packaged software investment, shown in Figure 1. First, the CSNA determines total domestic production of pre-packaged software, based on the value of total sales of the producers of software. In Canada, pre-packaged software is produced almost entirely in the software publishing industry (NAICS 511210), sales data for which are taken from Statistics Canada's annual surveys of Computer Services, and International Transactions in Commercial Services.

To this amount, CSNA adds the margins on domestic sales[13] (based on IO benchmarks) and the value of imports (using Balance of Payments (BOP) and merchandise trade data). This new figure is equal to the total domestic supply of software. From total domestic supply, the CSNA subtracts the value of exports (again from trade data) and the value of personal expenditure by households on software, from Statistics Canada's Annual Survey of Household Spending. This new figure is total domestic expenditure on software – the only remaining adjustment before arriving at final investment in software is to

13 Margins reflect the value of purchaser prices, which will include distribution costs, taxes, and other costs not reflected in the producer or "at-the-gate" factory price.

Figure 1

Commodity-Flow Method for the Estimation of Pre-packaged Software Investment in the CSNA



Source: CSLS based on Jackson (2002).

remove intermediate spending, which is largely software purchased to be embedded in hardware. To estimate intermediate spending on pre-packaged software, the CSNA deducts the input expense of the software publishing industries based on IO estimates.

The methodology used by the BEA in the United States is essentially the same. The BEA begins with total domestic production, based on data from the Census Bureau's quinquennial Census of Services Industries and Census of Manufacturers in its benchmark year; in non-benchmark years, the BEA uses receipts of industries involved in producing software from survey data. From this total, they deduct intermediate purchases and changes in inventory. Data on intermediate purchases are based on input-output estimates from the computer manufacturing industry based on the census of manufacturers; in non-benchmark years, the shares are assumed to be the same as the most recent benchmark year. Inventory changes are based on IO estimates in benchmark years only; the value of inventory changes in non-benchmark years is assumed to be zero due to a lack of data. This adjustment is equal to the total domestic supply of software for final use; the BEA deducts exports from and adds imports to domestic supply in order to produce an estimate of total final investment in software.

Differences in the Estimation of Pre-packaged Software Investment

There are two main differences in the estimation of pre-packaged software investment in Canada and the United States.

First, Statistics Canada and the BEA arrive at their initial value of total domestic software production via slightly different methods. Statistics Canada begins with producer prices prior to shipment, and adds margins on sales based on estimates from IO data. The U.S. methodology, on the other hand, is based on receipts and is at purchaser prices. In principle, margins on sales should be equal to the difference in producer and purchaser prices, so these methodologies are equivalent.

Second, the BEA explicitly adjusts for changes in inventory in benchmark years, while the CSNA at Statistics Canada makes no adjustment for inventory changes in any year. Data from U.S. benchmark years indicate that inventory changes have traditionally been very small, below 0.2 per cent of the value of purchased software in benchmark years, so the magnitude of this discrepancy is likely to be extremely small. This is unsurprising, considering that when designing their methodology, the BEA believed it was valid to omit this step for every non-benchmark year.[14] This is because most changes in inventory will already be accounted for through production and sales data.

The most important adjustment, the deduction for intermediate purchases of pre-packaged software, is estimated using essentially the same methodology in Canada and the United States.

14 Benchmark years are based on the quinquennial censuses, thus occuring every five years.

There is an additional complication in regard to the estimation of business sector software investment. In Canada and the United States, business sector software investment is calculated as a residual by deducting government purchases of software, which are known from administrative data. The business sector data cannot uniquely identify and exclude software investment by non-profit organizations and charities. This is not an issue for comparing the data, since we are comparing software investment by the same establishments in both countries. However, if software investment per worker and the relative size of the non-profit sectors in Canada and the United States are not comparable, then estimates of the gap based on these data will differ from the true business sector gap. This bias cannot be quantified without uniquely identifying software investment, which is the very same reason it exists. Nevertheless, the non-profit sector is likely small enough in both countries that the contribution to the total gap of software investment by those establishments is relatively small.

Having reviewed these factors, it appears very unlikely that measurement differences account for any significant portion of the extremely large gap in pre-packaged software investment per worker. This means that Canada's very low level of investment per worker in pre-packaged software, which was just a quarter of the United States' level in 2009, is largely unexplained.

Measurement of Custom-designed Software

The measurement methodology of custom-designed software in Canada and the United States is exactly the same as for pre-packaged software. The description of the commodity-flow method in Figure 1 applies to custom software as well, and there are no major differences in the overall methodology. There is, however, one key difference in the calculation of intermediate purchases. Statistics Canada is able to identify all intermediate purchases of software, but is not able to uniquely identify pre-packaged and custom software; all intermediate software purchases are therefore assigned to pre-packaged software. The BEA, in contrast, only identifies intermediate purchases of pre-packaged software, and reduces custom software by the same amount. In general, these intermediate purchases are difficult to measure, and so a fair amount of judgment was required to develop these methodologies. The estimates of intermediate purchases are always continually revised based on benchmark shares and software investment estimates.

The difference in the methods used to account for intermediate purchases cannot affect the overall gap or the gap in software investment, but it will affect the gap by software type and the share of software investment in each type of software. This is because Statistics Canada, by explicitly assigning all intermediate purchases of software to pre-packaged software, reduces the share of software investment in pre-packaged software, and increases the share of investment in custom software. This explains some of the difference in the composition of software investment in Canada and the United States.

However, total intermediate purchases of software—meaning both pre-packaged and custom-designed—software comprised only 4.6 per cent of software investment in 2009, according to IO input estimates from Statistics Canada. Even reducing the share of custom software and increasing the share of pre-packaged software by this amount only makes a modest difference to the distribution software investment in Canada. This explains only a small percentage of Canada's large gap in pre-packaged software investment per worker.

More to the point, however, this difference in the treatment of intermediate purchases does not affect total software investment. Based on our analysis in this section, we conclude that measurement differences in custom-designed software cannot account for a significant portion of the Canada-U.S. ICT investment per worker gap. The methodology used by Statistics Canada and the Bureau of Economic Analysis for both categories of purchased software is, in fact, largely the same.

Non-capitalized Purchases of Software

Investment data in Canada and the United States only include capitalized purchases of software. For the two categories of software investment considered, this refers to two types of purchases: (1) leased or licensed software, which are considered investment made by the lessee in both countries, and (2) purchases of either prepackaged or custom software. In recent years, cloud computing has emerged as a new technology, but its use is generally governed by Software-as-a-Service (SaaS) agreements, which are not included in either of the preceding categories. SaaS agreements are considered services, not assets, and so will not be classified as fixed capital formation. From the perspective of capital use, however, SaaS agreements are an example of extracting capital services from existing capital stock.

The potential measurement issue is that cloud computing agreements may be more appropriately considered investment, as they do increase the amount of software available to a worker. SaaS agreements therefore have the potential to affect the allocation of software investment estimates in two ways. First, domestic production of cloud computing software will be considered investment by the owner of the software, while the expenditure of the establishment using the software as part of a SaaS agreement is considered to be a trade in services. This means that the allocation of investment on an ownership basis, rather than a use basis, may be misrepresenting ICT investment per worker by industry. Second, the same allocation problem exists with respect to trade; SaaS agreements with non-residents will not affect estimates of software investment, even though they may increase or decrease the software available for domestic use. A third issue, arising from the second, is that if the capital services extracted from cloud computing software held by non-residents are better considered investment, then it is possible that software investment is currently under- or overestimated.

Existing data in computer and information services trade, however, are not currently capable of uniquely identifying SaaS agreements to allow us to quantify to what degree this may affect estimates of software investment. As the vast majority of ICT-related imports in both countries tend to be for data processing services, it is unlikely that a large number of SaaS agreements are crowding out capitalized purchases of software in Canada or the United States.

In 2011, for example, the share of computer and information services imports in computer and data processing services in the United States was 92 per cent, according to U.S. Trade in Services data. The same detailed data are not available on CANSIM, but the data on trade in services (available in CANSIM 376-0033) indicate that Canada has a trade surplus in computer and information services. A trade surplus means that Canada is a net exporter of computer services, which is not consistent with the hypothesis that a significant volume of SaaS imports are leading to software investment in Canada being underestimated. We find that it is very unlikely that this complication has a significant impact on the gap, but as cloud computing grows, more detailed data measuring purchases of these services is warranted.

Measurement of Own-account Software

We focus now on own-account software investment, motivated by the fact that it was responsible for 35.1 per cent of the Canada-U.S. ICT investment per worker gap in 2009, and that it tends to account for approximately a third of software investment in both Canada and the United States. Business accounting practices are even more inadequate for investment survey data to accurately measure own-account software, compared to pre-packaged and custom software. Indeed, in our interviews with Statistics Canada, the staff administering the CES indicated that while the response rate for the survey overall was more than satisfactory, the response rate for the section on own-account software was extremely low. This challenge has led to the development of indirect methods for estimating own-account software in Canada and the United States, which we describe in this section. We have previously identified that own-account software investment was responsible for 35.1 per cent of the total Canada-U.S. ICT investment per worker gap in 2009; this extraordinary contribution to the gap motivates our investigation into how estimates of own-account software investment are produced.

At the outset, we note that the methodology to measure own-account software used by the CSNA in Canada was largely based on the methodology used by the BEA in the United States. Any sources of measurement error are therefore likely to be symmetrical—they will introduce the same bias into the estimates of both countries, which will not have a clear effect on the gap. It is therefore unlikely that differences in measurement methodology will account for a significant portion of the Canada-U.S. gap in software investment per worker. Nevertheless, we provide an explanation of the methodology and note where they differ in this section.

Cost-based Methodology for Own-account Software Investment

Own-account software is not bought or sold on a market, and as a result, it has no market value comparable to the purchaser price values we use for determining final investment in purchased software. Consequently, the CSNA and BEA use a cost-based approach to measuring investment in own-account software. The cost-based methodology used by Statistics Canada is shown in Figure 2.

The CSNA methodology uses labour and non-labour costs of own-account software development to estimate the value of own-account software. The process begins with the total labour income of software developers, deducting the labour costs of other activities software developers are engaged in, and adding the non-labour cost of own-account software development. Non-labour costs include the depreciation of machinery and equipment, utilities, travel, property and other taxes, and overhead, including personnel, accounting, and procurement.

From Figure 2, there are four values that must be computed for the methodology used in Canada: (1) the labour cost of software developers, (2) the proportion of their labour cost that produces software for sale or embedding in hardware, (3) the proportion of their labour cost not spent on developing own-account software, and (4) the cost of other inputs. The methodology and data required in the United States are essentially the same.[15]

Each step in this process is based on data from either the census or surveys, except for the two deductions. The first deduction, for embedded software and software for final sale, is slightly

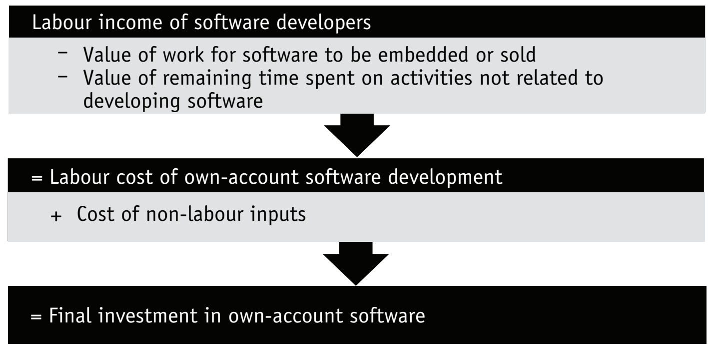
15 The BEA methodology for current-year quarterly estimates is different from what is described here, but our focus is on the annual estimates, which follow this methodology.

different in the two countries; we leave this issue for the next section. The second deduction subtracts 50 per cent of the remaining labour income of software developers, on the basis that software developers only work on developing own-account software for about half of their time. This is based on Boehm (1981), which found that software developers in the United States used 62 per cent of their time to develop software. The BEA and Statistics Canada arbitrarily reduced the share to 50 per cent, on the basis that this is an approximate exercise. They were also motivated by a belief, when this methodology was developed following the 1981 study this share is taken from (Boehm, 1981), that own-account software was becoming less important.

Differences in the Estimation of Own-account Software Investment

Table 7 reveals one difference in the methodologies used to estimate own-account software investment in Canada and the United States. This difference refers to the deduction for embedded software and software for final sale: in Canada, this deduction is based on an estimate that software developers account for roughly 1 per cent of all wages, salaries and supplementary income in industries not engaged in producing software for sales or embedding it in hardware. The CSNA uses this percentage to cap the labour cost of software developers in software producing and developing industries, on the basis that any labour cost above this amount must be for the purpose of producing software to be embedded or sold. The BEA performs the same adjustment, but it is based on 1 per cent of the employment of software developers, not 1 per cent of their income. Given different average wages, this will result in a different share of income being excluded. However, both Canada and the United States have verified and adjusted these shares using survey data, so any inconsistency resulting from this difference in methodology will reflect a real difference in the production of own-account software in Canada and the United States.

Figure 2
Methodology for Own-account Software Investment in the CSNA



As this is the only apparent difference in the methodologies used by Statistics Canada and the BEA to estimate own-account software, we conclude that there are no significant differences in the methodology used to measure own-account software in Canada and the United States.

Impact of Wages on Own-account Software Investment Estimates

The previous section discussed the cost-based methodology for estimating own-account software in Canada and the United States, which relies heavily on the labour income of software developers, and determined that the methodologies are largely the same.

However, the fact that U.S. salaries are greater for software developers is a conceptual challenge to this cost-based approach to valuing own-account software. In theory, a software developer with the same skill level could earn more, and contribute to a greater level of own-account software investment, simply by virtue of being employed in the United States. This could occur even if a software developer in each country produced precisely the same software for

Table 7
Data Sources for Own-account Software Estimates in Canada and the United States

	Data source in Canada	Data source in the United States
Labour cost of programmers	Census of population	BLS occupational employment survey
–		
Deduction for embedded software and software for sale	Cap of 1 per cent of the labour income of employees in software producing industries	Cap of 1 per cent of the employment of computer programmers
Time spent not developing software	50 per cent reduction of remaining income assumed	50 per cent reduction of remaining income assumed
+		
Non-labour inputs	Estimate non-labour inputs from labour inputs, based on cost structure of custom software production from Survey of Computer Services	Estimate non-labour inputs from labour inputs, based on cost structure of custom software production from Census of Service Industries
=		
Final investment in own-account software		

Note: The labour cost in both countries is adjusted to include benefits, employment insurance, public and private pensions, performance pay, etc., in order to provide a comprehensive reflection of the cost to employers.

their employer to use. In this case, the greater level of investment in the United States does not reflect differences in software investment, but instead only reflects the fact that software developers in the United States earn a salary premium relative to their counterparts in Canada. This section explores this conceptual challenge, examining how own-account software investment in Canada would change if software developers in Canada earned U.S. wages.

Our methodology to produce an estimate of how this wage gap has affected the Canada-U.S. ICT investment per worker gap is as follows. We use employment and wage data from 2005 to establish a wage gap; 2005 is chosen because it was a census year in Canada, so we have the greatest level of detail for employment and average earnings in this year. Second, we use the wage gap and the data we have for own-account software investment for 1998-2009 to see what impact the difference in wages between Canada and the United States for software developers had based on that data. This allows us to provide an estimate of the difference in wages of software developers and its impact on the Canada-U.S. ICT investment per worker gap.

Differences in the Labour Cost of Software Developers

Statistics Canada and the Bureau of Economic Analysis use a cost-based methodology described in the previous section to estimate own-account software. The labour cost of software developers is the primary input—some of this cost is deducted for time spent on other work, and the remaining cost is increased using the ratio of operating expenses to labour costs. All of these relationships are proportional, so an increase in labour costs would, in this methodology, also result in an increase in the estimated non-labour inputs.

The software developers in Statistics Canada's cost-based methodology correspond to NOC 2006 C071-75. The same data for the United States is provided in 2006 for the Standard Occupation Classification (SOC) codes that the BEA informed us they use in their cost-based methodology. The BLS Occupation Employment Statistics, from which we have taken these estimates, is the source of data used by the BEA to estimate own-account software. The SOC code numbers have changed since 2006, but they are substantially the same otherwise.

Based on these data and GDI PPP of 0.86 in 2005, software developers earned 52.31 per cent more in the United States, $74,910 in the United States compared to $49,183 in Canada.[16]

Before applying this estimate of the wage gap to our data on own-account software investment, we note three important differences. First, software developers earn much more (relative to the national average) in the United States than they do in Canada. Software developers in the United States earn nearly twice as much as the average salary for all occupations, compared to around 50 per cent more in Canada. Second, Statistics Canada includes web developers in their definitions of software developers, while the BEA does not. Web developers make up a relatively small share of employment, but we still note that the two countries have different definitions of software developers for the purpose of estimating own-account software. Third, software developers make up a significantly smaller share of total employment in the United States than in Canada. Their employment share of 1.79 per cent is 40.9 per cent higher than the U.S. share of 1.27 per cent.

It is surprising that own-account software investment per worker is so much lower in Canada than the United States given that there are relatively more software developers in Canada. This difference could be explained in part by a larger share of software developers in Canada working in industries that only sell or embed software in hardware. The wage difference, of course, also explains part of this discrepancy, but not all of it. Further research is required to determine precisely why own-account software investment per worker is so much lower in Canada than the United States despite greater employment of software developers.

We also note that the U.S. salary premium estimate of 52.31 per cent on the value of PPP for GDI, which we used to convert CAD to USD. Given similar growth rates of nominal salaries in Canada and the United States, the U.S. salary premium will change over time depending on the relative value of the CAD and USD as measured by PPP. To allow our estimate of the U.S. salary premium to change over time, we assume that the growth rates of nominal salaries in Canada and the United States are close enough that changes in the U.S. salary premium will depend only on changes in PPP.

Contribution of Salary Differences to the Gap

Using the data we have for own-account software investment from the Input-Output tables, we can use the U.S. salary premium for software developers to estimate own-account software investment in Canada adjusting for the Canada-U.S. wage differential for software developers. This will allow us to produce an estimate of the contribution of wages to the Canadian-U.S. ICT investment per worker gap for the 1998-2009 period, based on data for own-account software investment in Canada. This depends on our previous assumption that nominal growth of salaries of software developers in Canada and the United States is similar.

Using the adjusted values of own-account software, the total Canada-U.S. ICT investment per worker gap shrinks by approximately 4 percentage points in each year. This represents about 10 per cent of the total Canada-U.S. ICT investment per worker gap.

16 We use GDI PPP instead of exchange rates to convert investiment estimates in Canada to U.S. dollars because PPPs reflects differences in prices, providing a more accurate comparison of the labour costs of employing software developers incurred by firms in Canada and in the United States .

Table 8

Summary of Factors Contributing to the Canada-U.S. ICT Investment per Worker Gap

Factor	Contribution to the Gap in 2011	
	Percentage Points	Share
Canada-U.S. ICT Investment per Worker Gap	42.2	100.0
Non-Measurement Factors or Proximate Factors		
Labour Productivity	12.6	29.8
Industry Structure	2.4	5.7
Measurement-Related Factors		
U.S. Salary Premium for Software Developers	3.7*	8.8
Non-Quantifiable Factors Contributing to the Gap		
Dealer's margins on sales of used ICT equipment (measurement-related)		
Firm Size		
Education of Managers		
Business Attitudes and Culture		
Total Gap Explained by Factors	18.5	44.3

* Refers to the effect on the gap in percentage points in 2009, the last year for which data on own-account software investment in Canada are available

Note: These estimates are based on the most recent ICT data for Canada. However, the most recent estimates in Statistics Canada's FCFS tables are not consistent with the definition of the business sector used in the BEA Fixed Asset Accounts. According to the most recent ICT investment data from the Canadian Productivity Accounts (an alternate source of ICT investment data), the gap was 5.5 percentage points larger than estimated using the data sources this exhibit is based on for the year 2009. This qualifies, to some extent, the proportion of the gap we have explained in this report. If this effect persisted, the total gap would be 47 percentage points in 2011.

Conclusion

The main conclusion of this article is that measurement issues—defined as differences in definitions or methodologies used in the construction of ICT investment estimates by the Canadian and U.S. statistical agencies—are not an important part in the explanation of the Canada-US ICT investment gap. According to our estimates, measurement issues, and in particular the treatment of the estimation of the value of own-account software, only account for 4 percentage points of the gap, or about one tenth of the gap, and some measurement issues may actually contribute to underestimating the gap. The Canada-US ICT investment gap is *not* a statistical artifact.

The article is able to quantify a significant proportion of the gap. In 2011, ICT investment in the business sector in Canada was 57.8 per cent of the U.S. level, a gap of 42.2 percentage points. The largest proximate cause of the gap was the higher labour productivity level in the United States. *Ceteris paribus*, the gap would be 12 percentage points (30 per cent) lower if Canada had the same level of labour productivity as the United States. Canada's industrial structure, with a smaller employment share in information and finance industries (which have very high levels of ICT investment per worker) accounted for about 2 percentage points (or 5 per cent) of the gap. We summarize these findings in Table 8.

Together, these factors allow us to quantify approximately 18.5 percentage points or 44.3 per cent of the gap in 2011. In addition to this, differences in the treatment of transactions involving used equipment also affect the gap, but data are not available to quantify this measurement factor.

The remaining 24 percentage points (or 55 per cent) of the gap cannot be easily quantified and likely reflect factors such as: the smaller average firm size in Canada; better awareness of the benefits of ICT investment in the United States; differences in the education of managers; and potential differences in business attitudes and culture. It is important to recognize that Canada's ICT investment per worker is comparable to that of most other OECD countries.[17] Our gap is with the United States, not other countries. It is also important to note that we still have a large gap with the United States by a variety of other measures, including: the ICT investment share of GDP; the ICT investment share of total investment; ICT investment per hour worked; ICT capital stock per worker; and ICT capital stock per hour worked. In other words, the gap is robust across different measures of relative ICT investment performance.

Future research on this subject should be motivated by two key findings in this article. First, we consistently find that information and cultural industries and professional, scientific, and technical services make very large contributions to the gap. This strongly implies that the Canada-U.S. ICT investment per worker gap is the result of industry-specific factors. Any explanation of the gap must therefore include an explanation of why ICT investment per worker (and software investment per worker in particular) in these two industries is so much lower in Canada than in the United States.

Second, the lion's share (92.2 per cent in 2011) of Canada's ICT investment per worker gap with the United States is in software investment. A better understanding of this software deficit, and the reasons for its concentration in only a few industries, is the key to explaining the Canada-U.S. ICT investment gap.

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17 For details on international comparisons of ICT investment between Canada and other OECD countries, see Rai and Sharpe (2013).

Improving Canada's Productivity Performance: The Potential Contribution of Firm-level Productivity Research

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Abstract

Canada's recent productivity growth has been low by historical and international standards. Canadian and international studies have suggested this may be partly due to firm-level determinants. A chance to study this hypothesis has arisen from the improved availability of firm-level data through the Canadian Centre for Data Development and Economic Research. We argue that this creates an important opportunity for researchers and describe one attempt to capitalize on it by developing a research network.

Drummond (2011) has pointed out that output per hour worked in the business sector in Canada has only grown at 0.7 per cent per year since 2000, compared to about double that from 1973 to 2000 and more than five times that from 1947 to 1973. Labour productivity growth in the United States since 2000 has been more than triple that of Canada's, and the level of output per hour in the business sector and in manufacturing is only about 70 per cent of that in the United States.

Drummond (2011) goes on to consider a productivity policy target list he put forward five years earlier (Drummond, 2006), which included low, stable inflation, lower public debt-to-GDP ratios, free trade externally and internally, promotion of competition, removal of foreign ownership restrictions, the elimination of barriers to firm growth including high rates of taxation for large businesses, removal of work disincentives including those in Employment Insurance, reduction in regulatory burden,

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lower taxation of capital, lower marginal personal income tax rates, a shift from taxing income and capital toward consumption, improvement in the selection and integration of immigrants, increased investment in public infrastructure, and attention to literacy, apprenticeships and training. He then argued, subjectively, that Canada had implemented about 70 per cent of this agenda but, as noted, productivity growth has declined not increased—especially relative to the United States. Even though he writes, "This does not mean the agenda should not be completed," he asks the question, "if implementing 70 per cent of the original agenda did not bring on stronger productivity growth, can one be confident doing the remaining 30 per cent will do the trick?"

This question heightens the importance of research at the level of the firm to try to resolve this productivity puzzle and identify policies and actions to improve productivity growth.[2] Drummond (2011) raises some questions, perhaps most notably regarding the relatively small average firm size in Canada as compared to the United States, an average that did not increase significantly after the implementation of the North American Free Trade Agreement. Other questions have arisen regarding the management of Canadian firms, as will be discussed further in the next section.

While these are factors that increase the potential returns from Canadian firm-level research, we argue that the time is even more opportune because of a factor affecting the supply of such research. Statistics Canada's Centre for Data Development and Economic Research (CDER) has improved the accessibility of firm-level data for research purposes while maintaining security and confidentiality. In particular, the availability and potential "linkability" of data sets including firm-level tax data and new firm-level national accounts micro-data could permit analyses involving the relationships between a wide variety of financial variables and variables gathered in other surveys. This would provide insight into the dynamics of firm creation and destruction, the growth decision by firms (perhaps, e.g. affected by special tax and regulatory provisions for small firms in Canada or access to different forms of capital), managerial decisions on innovation and business strategies and much else. Such research requires resources. We discuss our attempt to develop a research network as one means to enhance research efforts in this area.

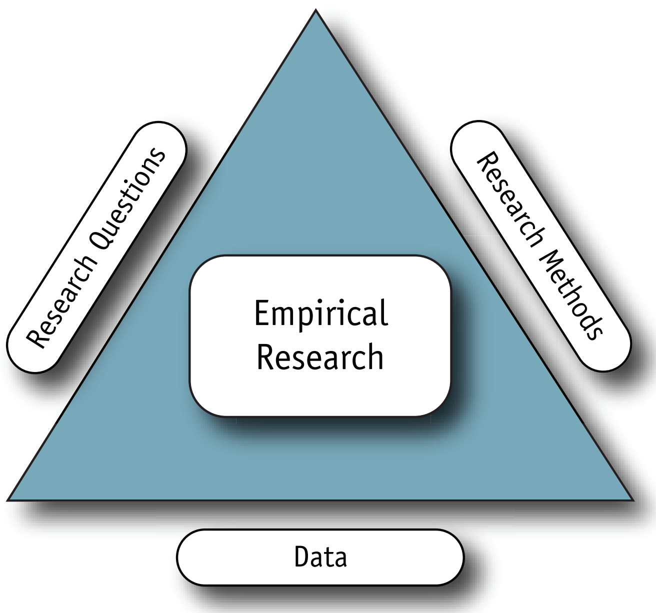
In the first main section, we describe briefly our argument for more firm-level research into the Canadian productivity puzzle. The second section provides some information regarding the research network we are helping to develop. The third section provides brief concluding remarks.

Firm-level Data and the Canadian Productivity Puzzle

Boothe and Roy (2008) survey some of the many previous contributions to the analysis of Canadian productivity and innovation and emphasize the importance of further research aimed at potential firm-level factors (firm size and scale, managerial skills and experience) as well as a number of industry factors that may interact with firm-level factors (competitive pressure/rivalry, foreign ownership/direct investment). As discussed, Drummond (2006, 2011) concurs, given the persistence of low pro-

2 It is perhaps a commonplace to the readers of this publication, but consider the following calculation as a reminder of the potential power of productivity policies. Suppose Canada has productivity growth of 1 per cent per year and we abstract from population growth or changes in labour participation. Given current Canadian flow GDP of $1.75 trillion and a real social discount rate of 3 per cent per year, the present value of permanently increasing productivity growth to 1.1 per cent per year has a present value of about $5 trillion, or almost three times annual GDP.

Figure 1
Framework for Empirical Research



ductivity growth in the face of a significant pro-productivity shift in public policy. Currie, Scott and Dunn (2012) suggest excessive risk aversion by firms and an insufficiently competitive environment are important factors behind low productivity growth in Canada. Currie and Scott (2013a,b) focus on low investment at the firm level and its implications for management, finding in a survey that 36 per cent of Canadian companies mistakenly believe that they are investing more than their peers when they are in fact not.

This misperception seems to be a management issue. If so, it is consistent with findings of Bloom and van Reenen (2007 and 2010) that international differences in productivity are related to differences in observable variables related to management skill, such as the education level of managers. Bloom (2011) finds that such differences could account for the difference between productivity levels in Canada and the United States, while Brouillette (2013) finds that Canadian manufacturing enterprises facing stronger competition are those adopting best management practices, and in turn having better economic and innovative performance.

Besides firm size and managerial skills and experience, another important, related issue that has arisen is heterogeneity, or differences, in productivity levels across firms.[3] Just as heterogeneity in productivity performance across countries may shed light on economic policies, heterogeneity across firms may suggest reasons for the relatively poor measured productivity performance of some Canadian firms relative to those of much higher productivity. Other important firm-level productivity issues are the use of information technology (Rai and Sharpe, 2013) and learning-by-doing within the firm (Levitt, List, and Syverson, 2013). There has been considerable research regarding the linkages between trade and productivity at the firm level (Baldwin and Gu, 2003, 2009; Baggs, 2005; Lileeva, 2008; Lileeva and Trefler, 2010) and in particular whether it is firms with higher productivity levels that export or whether some aspect of the decision to export can be causal in improving productivity. Still other examples are: firms and intellectual property (Law, 2004); innovation and firm productivity (Therrien and Hanel, 2012); the relationship of firms to university research (Agrawal and Henderson, 2002; Agrawal and Goldfarb, 2008); firm size and productivity (Dixon and Rollin, 2012); firm finance, particularly at early stages (Huynh and Petrunia, 2010; Huynh, Petrunia and Voia, 2011; Kelly and Kim, 2013) and more broadly financial sector productivity (Cummins, Dionne, Gagné and Nouira, 2009). In any case, these are all issues that can clearly be better studied and understood with detailed business micro-data.

Empirical research can be described as a triangle involving the research questions, the research methods and the data (Figure 1). We

3 See Syverson (2004); Fox and Smeets (2011); and Gandhi, Navarro and Rivers (2011) for examples.

have touched on the research questions; let us turn to methods and then to data. On methods, there has been an international explosion of research into productivity. The papers in this journal continue to speak to this, as do surveys such as Syverson (2011). Ackerberg, Benkard, Berry and Pakes (2007) provide a reasonably recent survey of econometric tools.

Finally, we turn to the third part of the research triangle, data. As discussed in the introduction, an important stimulus to this endeavour has been the development of CDER at Statistics Canada,[4] which has improved the potential access for research to business micro-data. The available data sets are very rich although not always ongoing. They are well described on the CDER website.

Surveys include the Annual Survey of Manufacturing (linked with the Export and Import Registry Database); the Survey of Innovation and Business Strategies (responses from firms on their innovation and competitive positioning); the Survey of Financing of Small and Medium Enterprises; and the Workplace Employee Survey (which linked workplace and employee surveys and has since been discontinued).

Administrative data include the export and import registry; customs data; company-level capital and investment data compiled from corporation income tax filings; and the Longitudinal Employment Analysis Program.[5] There is also the constructed National Accounts Longitudinal Micro-data file designed to track and analyze GDP and employment at the firm level and across firm-size categories.

In addition to the key issues of data confidentiality and security, there is an issue of cost as the data use is not free of charge. But there are two economies of scale. First, researchers in effect pay a "fixed cost" in learning to use the data efficiently. Once that is paid, subsequent applications are easier. They are also likely to collaborate with other researchers, so that the fixed costs fall over time. Second, there are also tangible fixed costs in such matters as data linkage. Once two data sets are linked, subsequent researchers may not have to bear those costs again. We also note that while survey data are an important part of CDER, administrative data are equally important and could contribute significantly to future empirical advances (Card, Chetty, Feldstein and Saez, 2011).

Let us turn to some further considerations regarding firm-level productivity research. One is how this type of research may be influenced by the debate about measurement of total factor productivity in Canada, as seen in the symposium on the measurement of multifactor productivity in Canada in the Fall 2012 issue of the *International Productivity Monitor*—specifically Diewert and Yu (2012); Gu (2012); Diewert (2012); Schreyer (2012); and Harper, Nakamura and Zhang (2012). Diewert and Yu (2012) argue that Canadian multifactor productivity has grown much faster over the past fifty years than Statistics Canada estimates indicate. In terms of firm-level empirical research, this debate heightens the importance of increased use of business micro-data (Baldwin and Gu, 2013). But we note that it does not change our view of the immediate problem as both the Diewert and Yu (2012) and Statistics Canada estimates find that multifactor productivity growth since the year 2000 has been essentially zero. Even over the longer term, the differences between the Diewert and Yu (2012) and the Statistics Canada estimates largely involve different contributions from multifactor productivity growth and the contribution of capital growth to labour produc-

4 www.statcan.gc.ca/cder-cdre/

5 The Longitudinal Employmeent Analysis Program has longitudinal payroll enterprise data linked through the T2-LEAP file to sales, gross profits, firm equity and assets. It is also linked with the Export and Import Registry Database.

tivity growth, which advances at roughly the same rate in both the Statistics Canada and Diewert-Yu time series. Their estimates also largely agree that labour productivity per hour has been growing more slowly in Canada than it has in the United States.

A second consideration is that there may be alternative firm-level explanations of the productivity growth slowdown relative to the United States. For example, one possibility is that the significant reduction in aggregate demand in the 2000s was met in the United States with a reduction in employment rates in a way that reduced the number of low-productivity workers in the economy.[6] In Canada, there was not as large a reduction in employment rates albeit with lower productivity growth. Firm-level data could also be used to test this explanation. And while the comparison with the United States can be instructive, it does not solely drive the interest in higher Canadian productivity growth, which is intrinsically desirable.

A third consideration is that there has already been significant research with firm-level data. As noted, some of this is surveyed in Boothe and Roy (2008) and there have been a number of recent papers, some of which we have cited above. An important set of such research comes from Industry Canada and Statistics Canada, in particular the group that John Baldwin directs at Statistics Canada. Very recent papers that focus on the firm level include Baldwin, Leung and Rispoli (2013), Brown and Rigby (2013), Ciobanu and Wang (2012) and Tang (forthcoming). However, some of the data opportunities are quite new, particularly those opened up by firm administrative (tax) data and in the new longitudinal National Accounts firm-level microdata. It is our belief that the new data accessibility has the potential to transform empirical firm-level research outside the Government of Canada and that the interaction will increase the impact of existing government agency research programs.

To conclude this section, let us describe our overall objectives. Ongoing Deloitte research (see Currie, Scott and Dunn, 2012; Currie and Scott, 2013a and 2013b) discusses government policy but also pays significant attention to what firms as well as other participants, such as universities, should do to improve productivity, independent of government policy. Hence while our intermediate target is to build a strong and sustainable program of research and knowledge transfer, the larger goal is not just to understand the issues and to inform public policy, but also to provide information relevant to the decisions of private firms (and nonprofits) as to which potentially productivity-improving practices are backed by Canadian empirical evidence. An individual firm, particularly a small or medium-sized firm, is likely to under-invest in such information because it cannot capture all the benefits (because of taxation, gains to its workers and imitative gains by its rivals). This is the classic public good argument often used to support public provision, of which a famous example is government agricultural departments distributing to farmers free information on innovation. It further seems plausible to us that better information on best practice may also illustrate to each firm the advantages of acquiring further private information specific to it. None of this precludes the possibility that there may be other kinds of government policies that may affect firm behaviour, for example pro-competitive

6 Another explanation is that the weak productivity growth in Canada is driven by particular industries, such as oil and gas, and that in turn productivity growth estimates for these industries may be biased by significant and difficult measurement issues. Our view is that this is an argument for more disaggregation rather than less. For example firm-level data allow better study of the mix of exploration, development and extraction in different firms and how that may affect measured productivity. We do not dismiss the significant measurement issues at the firm level but believe that these problems can be resolved and that industry aggregation presents its own analytical problems.

policies that could possibly push firms towards more aggressive innovation.[7]

The Network

In late spring 2012, we and a group of like-minded researchers were awarded a Social Sciences and Humanities Research Council of Canada (SSHRC) Partnership Development Grant (PDG) to build a Network to Study Productivity in Canada from a Firm-Level Perspective.[8] Network institutional partners are Industry Canada, McMaster University and the TD Bank. As should be clear, the Network has an ongoing collaboration with Statistics Canada and has been inspired by the research program of Deloitte (e.g. Currie, Scott and Dunn, 2012; Currie and Scott, 2013a and 2013b).[9]

Researchers are encouraged to contact the Network to explore collaboration and future initiatives. One purpose of the Network is to help develop the kinds of data-access partnerships with CDER as described on its website: "strategic partnerships that are entered into with highly trained economists to undertake important policy-relevant economic research on topics such as *productivity*, international trade, investment patterns and firm dynamics, while assuring the confidentiality and security of data" (emphasis added). Accordingly the SSHRC grant includes funds to assist researchers at Canadian universities (and in rare cases those from non-Canadian universities) with expenses to travel to Ottawa to access the data at CDER and perhaps with some costs incurred in accessing the data itself. The SSHRC funding also includes funds that can be used to help support students (most probably but not exclusively doctoral students) at Canadian universities who are working in this area. The Network is also open to approaches that study firms (and public sector organizations) whose data sources are not housed by CDER.

The Network also seeks researchers from the private sector, think tanks, government and academia to participate in our future workshops and conferences. So far it has had a workshop in Ottawa November 1-2, 2012 and sponsored four sessions and two meetings at the Canadian Economics Association annual meeting in Montreal, May 30-June 2, 2013. It held a workshop at the Rotman School at the University of Toronto on October 25, 2013. It again plans to sponsor sessions at the Canadian Economics Association annual meeting in Vancouver (May 29-June 1, 2014). It is a co-host along with Industry Canada and principal host Carleton University of the American Productivity Workshop VIII (http://northamericanproductivityworkshopviii.yolasite.com/) where it is sponsoring sessions featuring Dale Jorgenson of Harvard University and John Haltiwanger of the University of Maryland. There are also some individual network projects with the first few working papers now posted on the Network website.

Finally, it is important to emphasize that the SSHRC support is a Partnership *Development* Grant. Through the above activities, and with the collaboration of more researchers, the goal is for this effort to blossom into a broader Network with significant and sustained funding,

7 We note a finding from the Council of Canadian Academies (2013) that "Canadian firms have been as innovative as they have needed to be".

8 The grant is for approximately $200,000 over two years. The steering committee is Don Drummond (co-investigator), Annette Ryan (co-investigator) and Michael Veall (principal investigator). Other co-investigators are Ajay Agrawal, Avi Goldfarb, Ignatius Horstmann and Daniel Trefler of the University of Toronto; Audra Bowlus, Lance Lochner and Salvador Navarro of Western University; James Brander of the University of British Columbia; Svetlana Demidova of McMaster University; Robert Gagné of HEC Montreal; Stephen Law of Mount Allison University; Alla Lileeva of York University; Robert Petrunia of Lakehead University; and Marcel Voia of Carleton University.

9 The Network's website is www.economics.mcmaster.ca/productivity.

that will tap still under-utilized micro-data sources and shed light on the reasons for Canada's weak productivity growth.

Conclusion

The ultimate objective of productivity research is for Canada to benefit from the improved economic growth that can spring from a better understanding of business-level drivers of productivity. We argue that empirical research centred on firm-level data should be a focus, in part because Canadian and international studies point to its potential importance and partly because newly developed and accessible firm data make it feasible. We describe one attempt to capitalize on this opportunity through the development of a research network.

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Mastering Leviathan: A Review Article on *Growing the Productivity of Government Services*

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Abstract

This review article evaluates the book *Growing the Productivity of Government Services* by Patrick Dunleavy and Leandro Carrera, which examines how government outputs can be measured and how the United Kingdom has strived to improve government productivity. The author finds the book valuable, as it shows how methodological advances reported in Sir Tony Atkinson's recommendations on reporting government outputs can be put into practice. Furthermore, documenting how government productivity can be improved in the United Kingdom provides valuable lessons for other countries. The potential of technology to improve government productivity is emphasized in the book, although the author suggests that a more basic role of reporting on government output will spur reform. Strong management skills will be important not only for effective implementation of IT but also for broader improvements in government productivity.

The impact of government on the well-being of citizens is enormous. Most attention is paid to highly visible policies such as interest-rate or tax policies, but a vast array of services are provided by government that affect the daily lives of citizens, ranging from the provision of health care to the collection of taxes and the issuing of passports. The objective of the book under review is to place all of these changes in government services in a wider context through the lens of productivity so that the interaction between citizens and the state can be improved. Monitoring the productivity of providing government services could provide an impetus to improving them.

With the scale of services being provided by government, improving their productivity could have significant positive impacts on living standards. But there is currently no way of tracking any changes that take place, or even to put the size of the challenge in context. These are the direct goals of *Growing the Productivity of Government Services* by Patrick Dunleavy from LSE and Leandro Carrera from the Pensions Policy Institute and King's College: how to measure government productivity in practice, and how it can be improved (Dunleavy and Carrera, 2013). The book does not prescribe in detail what must be done to improve productivity. Instead, what becomes apparent is that measuring the productivity of government services yields insights into

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how to improve government services; provides a benchmark for recording successes and failures; and highlights where policymakers' attention needs to be focused. Even relatively crude measures of government output can be informative. The book effectively refutes the pushback from naysayers that government services are too complicated to be measured.

The book builds on and applies the work of the *Atkinson Review*, which provided guidelines on measuring government output for the National Accounts (Atkinson, 2005).[2] It details the nitty-gritty of measuring the productivity of government services—ranging from levying customs duty to issuing passports—and examines the impact of information and communication technologies (ICT). Concrete lessons are highlighted. All of this is done in the context of a practical discussion of efforts by various government agencies in the United Kingdom to improve their productivity, some of which succeeded while others faced more challenges. Some government services are provided through centralized agencies throughout the United Kingdom; for others, the book focusses on England rather than on the devolved governments in Northern Ireland, Scotland and Wales.

The scale of activities reported in the book suggests that there are real opportunities to improve productivity in government. Much is made of the potential contribution of ICT, but it is noted that investment in ICT requires workplace reorganization to be effective. As is made clear as well, however, policies to improve the operations of government can lead to problems.

The book discusses the delivery of government services rather than the policy choices on which services should be provided. For example, it is the administration of the tax system that is discussed, not the appropriate balance between consumption and income taxes. Implicitly, this approach emphasizes that improving government productivity should be in the interest of all parts of the political spectrum. The book includes a discussion of measurement methodologies and of economic tools to measure productivity. Essentially, this is a guidebook to productivity in government from the viewpoint of public administration rather. Appropriately, there are no precise recommendations on what should or should not be done. Nevertheless, the authors draw on recent experience on, for example, the outsourcing of government services to explain what problems might arise. This review cannot do justice to all of the intricacies in administrative policies and measurement challenges that are explored, but will instead concentrate on giving a flavour of these issues and discuss potential implications of this valuable work.

This review proceeds as follows. The first section summarizes the content of the book. After introducing the conceptual framework of government productivity used in the book, the productivity performance of individual government departments in the United Kingdom is examined by the authors and policy lessons are summarized. The second section of the review examines issues that reporting government productivity might bring to the fore, including comparing productivity in government and business, and wider issues of controlling and motivating the bureaucracy. The review then concludes by agreeing that government productivity needs to be measured, but that wider changes also need to be fostered beyond investment in ICT before government productivity can be improved.

Measuring Government Productivity

The current practice in the National Accounts of most countries is to measure the value of government-provided goods and services by their cost of production. As such, the National

2 The *Atkinson Review* was summarized and discussed in ab Iorwerth (2006).

Accounts only include inputs into these goods and services. The *Atkinson Review* gave an impetus to measuring directly their output instead. As an example, the input into teaching normally captured in the National Accounts is the salaries of teachers, and the quantity of this input might be hours for which teachers are paid (which may or may not be in front of a class). The suggestion in the *Atkinson Review* was that the number of pupils taught should be an output measure. For health care, the input might be the hours of work by doctors and nurses, but an output measure might be the number of procedures conducted or the number of complete treatments administered. These outputs could then be weighted and aggregated by the unit cost of providing them to obtain a value suitable for the National Accounts. OECD recommendations in these areas are discussed in ab Iorwerth (2012).

In this conceptual framework, it becomes important to distinguish between outputs and outcomes. Outcomes are those results valued by consumers and society at large, such as a healthier individual or a more educated person. Actions by individuals as well as government can contribute to those outcomes, so it is a challenge to appropriately capture the outputs of government that contribute to desired outcomes. Making a distinction between outputs and outcomes becomes important in analyzing government services because it provides a clearer identification of what government does and what it can contribute.

By following this approach, the productivity of government can be measured by comparing outputs and inputs, which then allows for (Atkinson, 2005):

1) Better data for macroeconomic management through the National Accounts;
2) Assessment of overall economic performance and welfare; and
3) Development of government performance targets.

So what happens when government productivity is not measured? The first interesting contribution of this book is in classifying current policy initiatives on improving government performance into their potential impacts on government productivity. Given austerity policies implemented by governments around the world, for example, there is a risk that expenditure cuts may result in a greater decline in output than inputs because measures of outputs are not available.

The first concept that the authors introduce is *effectiveness*. Effectiveness is the level of outcomes per unit of input. Having a healthier person per unit expenditure on healthcare is clearly ideal, but the authors argue that effectiveness is too subjective a measure. In many cases policy effectiveness might be guided by values and beliefs.

Efficiency is defined as minimizing the level of resources to achieve a given level of output. Improving efficiency leads to a static view of improving operations as one-off events. Efficiency drives tend in practice to lead to cuts in services or lowering the quality of services, so productivity could decline. A similar result can come from *efficiency dividends*, whereby a department's budget is automatically cut, with revenues reallocated to priority areas.

Governments may also undertake *value for money* audits when external auditors examine whether targets and goals are being met. Although valuable, audits tend to be one-off exercises using ad hoc methodologies that cannot be replicated across departments and do not provide for continuous measurement of productivity.

Many of the austerity policies implemented around the world fall into the categories outlined above, but they do not aim directly at improving government productivity. Some of the authors' concerns about the potential for unintended consequences are reflected in the observations of a Canadian public servant describing the cutbacks undertaken in Canada during the 1990s: "We did what all good businesses do when they first see the signs of trouble. We focused on the costs of inputs [but we] did not do a rethinking of our business and business processes" (Savoie, 2003:144). Whereas the authors of the book under review would agree with the second part of the quote, they would probably disagree with the first. Concentrating on cutting inputs without knowing what outputs are being cut as a consequence would be a risky proposition in the private sector, but this is what governments generally do.

Accurate measures of output and productivity could inform decisions on where cutbacks might be easier, or at least lead to the appropriate questions. If productivity growth in a government agency was slow over many years, were there inherent reasons for this situation, or was there scope for better performance? A further concern with current approaches is inadequate reflection on the quality of government services. Budget cuts during periods of fiscal retrenchment could be met by diminishing quality of service. Cutting costs through not answering phone calls or not resolving difficult cases is probably not what the architects of austerity have in mind. But this also means that productivity statistics for government need to capture quality, or the decline in output would be understated.

Ideally then, a measure of government productivity would show that cost cutting that leads to a greater-than-proportional lowering of government output would be reflected in lower productivity. Such a measure would integrate some notion of quality if perverse effects are to be avoided. The *Atkinson Review* strongly argued in favour of incorporating quality of outputs.

The authors of this book agree with that recommendation and show how it can be done in practice, along with the risks of not doing it. Although incorporating quality can blur the distinction between outputs and outcomes, the authors argue that not including quality can lead to many perverse effects.

An example of such unintended consequences is a hospital that processes patients carefully and gives them longer post-operative care so that its success rate with operations is high, whereas another hospital skimps on post-operative care and then needs to re-admit these patients. Measuring output as simply the number of operations would lead to higher output and productivity for the second hospital. Developing a quality-adjusted output measure is therefore necessary to avoid perverse incentives. Despite their concerns, the authors argue that such adjustment needs to be conservative, particularly for public services where there is not much scope for difference in quality. In the case of health services, quality adjustment is required because of the scope for significant variation in quality between providers. However, as not all aspects of quality can be measured, there is a risk of diverting attention from those aspects of quality that cannot be well measured.

In their discussion of measuring the productivity of hospitals in England, the authors delve into the details of how quality adjustment can be done in practice. Aggregate hospital performance is assessed by three quality measures: average patient waiting times, patient satisfaction, and the ratio of complaints resolved in target times divided by total complaints received per year.

The issue of hospital output has recently gained relevance in the United Kingdom where it is speculated that at a hospital in Mid-Staffordshire several hundred more patients died than would have been expected. The alarm was initially raised through analysis of mortality-rate data, suggesting they were abnormally high. Summary Hospital-level Mortality Indicator (SHMI) reports have been available for individual hospitals in England since October 2011. It would have been interesting for the authors to explore how greater provision of data on the performance of government-provided services could play a role in improving them.

A challenge in incorporating quality measures is identifying the actual elements of government service that citizens really value. The authors highlight two cases where what citizens cared about only became apparent after a crisis. The appropriate screening of passengers at airports turned out to be greatly valued after 9/11, and quality shading in this area was not appreciated. In the delivery of passports in the United Kingdom, it turned out that travellers valued punctuality far more than cost. The agency providing passports had tried to introduce small cost savings in providing new passports, but then bungled the implementation so there were delays of many months in issuing them. There is a risk that government bureaucracies themselves assume what citizens value rather than unearthing the reality; there should be no misalignment between "business" objectives and what citizens actually want.

Case Studies

The core of the book is a series of case studies of measuring productivity for various government services in England. Each case study outlines the different challenges faced in analyzing and improving productivity. These challenges are introduced through first outlining what the objectives of the organization are, and the history of providing those government services. This context is very detailed—and perhaps too detailed for the general reader or for someone not familiar with the institutions—but it sheds light on why particular choices are made in measuring productivity and what aspects might be relevant in changing productivity patterns.

Table 1 outlines the output measures available for various government services in measuring government output; the cost weights used to aggregate outputs; and the appropriate quality adjustments (not all of these services are explored in the book). In the case of standardized outputs provided by a single government organization, the authors suggest that no quality adjustments are necessary, although many would debate this conclusion.

By delving into the intricacies of specific cases, the authors also show that productivity can indeed be measured and be informative in government, shedding light on the different opportunities that measuring productivity can bring. If a single agency is responsible for all provision of a service in a country, such as the tax-collection agency, then it is difficult to use the data to compare performance to other organizations (although international comparisons would be interesting). On the other hand, measuring the productivity of a hospital would allow greater within-country comparisons to be made.

Success stories in improving government productivity in the United Kingdom include the assessment of customs duty and the levying of taxes. The process of levying customs adopted automation earlier than other government departments, which the authors trace to its extensive links to business. This interesting comment on the varying responsiveness of government departments is not explored further, but it would have been interesting to find out more. As a result of automation, fewer customs checks were needed and clearance was faster, which the authors estimate to have more than tripled total factor productivity from 1997-1998 to 2007-2008, and increased labour productivity by even more. Because of this increased productivity, resources could be diverted to more strategic risk-based examination of cargo rather than random spot checks.

The authors concur with the managers of the customs agencies in arguing that it is too tricky to control for quality when measuring this output. However, it would be interesting to explore further aspects of quality in this area. This reviewer's expe-

Table 1
Suitable Output Measures for Productivity Analyses in Public Services Operated by National Government Departments or Agencies

Public Service	Activities	Cost Weights	Quality Weights
Social security	Major different social security benefits. The numbers of new benefits claims processed should be separately distinguished from the payment of existing ones (because they are much more expensive)	Unit costs for each benefit	Standardized procedures, so no quality measurement should be necessary.
Tax collection	Tax returns processed for main types of taxes handled by national tax agency, such as income tax, VAT or GST, business taxes, etc.	Share of administration costs published by the tax agency for each type of tax	Same as above
Customs	Total number of import and export declarations	Share of administration costs for processing imports and exports	Same as above
Prison service	Number of total prison population and the numbers of new prisoners admitted	Unit cost per prisoner	Potential indicators include escapes or access to drugs, or degree of overcrowding
Passport issuing	Number of passports issued	Unit costs for different types of passport services	Waiting times could be used as a proxy for service quality
Border protection	Total number of activities in border control, border enforcement, asylum and after-entry managed migration tasks	Unit cost or share of administration costs for each kind of activity	Complex service. Could have an indicator of quality such as proportion of cases appealed.
Driving and vehicle licensing	Total number of vehicle and driver transactions	Unit costs (such as average time taken per transaction)	Routine service

Source: Table 2.1, Dunleavy and Carrera (2013).

rience is that going through customs when entering the United Kingdom on a U.K. passport is straightforward, while entering Canada on a Canadian passport can bring about an experience bordering on harassment, leading one to wonder what the implications of the two systems were. Another interesting question is why passing U.K. immigration controls has been rapidly automated after the introduction of biometric passports, while such automation has lagged in North America.

Rather than the sharp increase in productivity at the customs agency, the tax authorities experienced a more continuous increase in productivity. Labour productivity in central-government taxation increased by about 50 per cent between 1997-98 and 2007-08, but this improvement progressed in fits and starts.

A more depressing picture of government productivity comes from the administration of social benefits. The authors are particularly aggrieved that the responsible organization—the Department of Work and Pensions (DWP)—moved to a telephone-based system just as the world moved to the internet. Furthermore, no electronic-transaction methods were developed for its benefit recipients from 1999 to 2005. According to authors' statistics, 20 years of reform led to zero change in the overall productivity of providing these services. Carrera and Dunleavy (2011) trace this lack of change not only to the frequent change in policy but also to the combination of a lack of IT background in senior management and IT staffers being 'mainframe guys'. Together, these factors lead to organizational conservatism.

There was essentially no increase in productivity in either issuing passports or vehicle licensing, despite these areas being ripe for technological change. The agencies responsible for these tasks seemed to have been a little bit too interested in becoming part of a move to issue identity cards in the U.K., expanding their "market", rather than in concentrating on their assigned tasks. The incomplete movement of forms online led to higher costs not only for the passport agency, but also for citizens. Filling out forms to obtain a passport became so challenging that the Post Office—a separate agency—offered to check the forms for applicants when they were mailed in (for a fee of course)!

In discussing productivity differences across similar units, Dunleavy and Carrera find, for example, that hospitals in London are less productive than in the rest of England, but are unable to pin down exactly why. By comparing performance across hospitals, they uncover complex relationships between the effect of management practices and ICT on productivity whereby one may offset the weaknessess of the other, but the benefits decline as the other improves. As the authors note, the research is preliminary but one can see an active and fruitful research path ahead.

Policy Lessons for Improving Productivity

Based on the lessons learned in the United Kingdom, the authors advance key elements to improve productivity growth in government:

1) **Keeping continuous focus on productivity**: Rather than occasional step-level changes to productivity, governments should maintain a continuous focus on improving productivity.
2) **If services are outsourced to the private sector, it is important to maintain the option of changing suppliers if the first contractor is not up to the job**: Hoping that government productivity might be improved simply by outsourcing service provision to private contractors may lead to disappointment. These contractors have, in many cases, become so large and entrenched that they are effectively monopolies, no longer given to improving government's productivity.
3) **Greater involvement of public servants in efforts to improve productivity**: The involvement of workers is often central to improving productivity in the private sector. Productivity in Southwest Airlines seems to have benefitted significantly from the suggestions of employees. On the other hand, the authors believe that there is considerably more suspicion of government workers, making leaders in the public sector less likely to involve them in attempts to improve productivity.
4) **Not using a large state—and implicitly a less productive state—as a means of combating inequality**: In a critique aimed more at continental European states or the political left, the authors criticize the tendency of using state employment as a means of achieving social goals. The indiscriminate creation of jobs for workers, regardless of skill, would inherently drag down productivity.

How Do Productivity Improvements in Government and the Business Sector Differ?

With the insights gleaned from the authors' analysis of government productivity, improvements in the private and public sectors can be compared. The first contrast is that innovation tends to be continuous in the private sector. Governments, on the other hand, tend to go for long periods with insufficient attention to government productivity, but then undertake sweeping reforms and deep cuts when there is a change in government. It is interesting to speculate why this might be the case: in the absence of data continuously available for government productivity, does the case for reform have to become obvious before action is undertaken? In determining where to allocate their scarce political capital, does the case for reform have to be so clear—as in the times of fiscal crisis—that politicians usually avoid reforming government services?

The drivers of productivity growth differ between government and the private sector. The failure of business to improve productivity compared to its competitors would ultimately see it go bankrupt, and its more productive competitors gain market share. Such resource reallocation by the market, from less successful to more successful firms, is a large part of 'automatic' year-over-year productivity improvements in the business sector (see, for example, Foster *et al.*, 2008). But productivity gains from such reallocation are not available in government because unproductive units are generally not shut down. Although there has been much discussion of allowing parents to choose schools for their children, for example, schools that fail to attract pupils are unlikely to be closed. Consequently, continuous improvement in internal productivity is more important in the government than in the private sector, because reallocation gains are less available in government.

The pattern of productivity improvement in the public sector stemming from the technological revolution wrought by the digital economy seems to have followed the path of the private sector in general. Initially, productivity increased through investments in new computer systems. Financial systems, data collection and transmissions, payment processes, internal communications and human resources management were made electronic so that the internal management of government could improve. Electronic systems also provided more flexible and convenient services to the public, such as easier filing of tax returns and the streamlining of information delivery. But harder tasks were then faced as businesses processes needed to be changed to maximize the productivity-enhancing potential of information technology (IT), as reviewed by, for example, Draca *et al.* (2009). It is at this stage that government appears to have struggled more than the private sector in improving internal processes, notably because of the sheer scale of government operations and the inadequate management expertise within it.

With the development of large IT systems, governments outsourced many tasks to private providers, which were invariably large corporations that could cope with the scale of conducting government operations. Unfortunately, improvements in government productivity were limited because this transfer was made without any reengineering of IT systems. But moving activities from a government department to a privately-controlled oligopoly is unlikely to drastically improve the quality of services, absent incentives unleashed by competition or an ability to write complete contracts (i.e. contracts that convey all possible contingencies). Private contractors acquired large blocks of work and did nothing to be innovative. As a result, contractors have evolved into a closed oligopoly and government is now overpaying. There are many cautionary tales here for recent Canadian suggestions that improved procurement by government can enhance innovation in the private sector (Industry Canada, 2011; PWGSC, 2013). If Canadian firms can have an easy life through government contracts, then their productivity performance might become even worse; instead, effective government procurement would see government become a demanding client, wanting the best from its suppliers.

The authors point out that, to improve productivity, government is particularly dependent on the "collective capabilities for analyzing what they do and working out ways to do it better." In other words, people and management matter. Bloom and Van Reenen (2007) have identified successful management practices to enhance productivity in private-sector firms. Hence, there is significant scope for more research on what is required to have continuous improvements in government productivity: are there different types of management skills needed in the public sector? Is their mix the same as in the private sector? How do the levels of management skills compare?[3]

One element that is likely to be key is organizational learning and innovation, as noted by the authors. A learning organization is one that learns continuously and transforms itself. Organizational learning goes beyond individual learning by incorporating collective experience of success or failure in developing new methods to improve the organization's performance.

In the private sector, a business may learn of mistakes in its manufacturing process from technicians and then disseminate this information to product designers and R&D staff. An interesting example in government service comes from the experiences of the U.S. Army in Iraq (Nagl, 2005). After the initial failure of combat tactics in Iraq, the military had to adapt and learn how to fight using different tactics and spread those best practices quickly. Whereas the incentives to avoid death may be an extreme form of competition leading to better productivity, the need for managers within government to react to failures through learning seems clear.

These differences between productivity performance in government and the private sector reflect the muted power of incentives in government, which leads to the question of whether these incentives could be changed. Simply replicating the salaries and bonus structure of the private sector would raise legitimate concerns from taxpayers, as the distaste in the United Kingdom over salary payments to BBC functionaries attests. Clearly there are no panaceas, but revealing more information on performance of individual organizations as a matter of course—rather than having to go through freedom of information laws—would likely be a step in the right direction. Not only would greater transparency bring scrutiny, but it would also encourage competition between providers of government services, such as hospitals and universities.

The Relationship between State and Society

The authors have great ambitions for the future of IT to transform relationships between citizens and the state. According to them, citizens and businesses will increasingly co-produce outputs, with government using online electronic processes—such as the interaction between government and business—to hasten passage through customs checks. An analogous argument is that innovation in the service sector is more likely to come from the interaction between producers and their clients, rather than from science-led research and development.

There are obviously social, organizational and hence political implications of these changes. Individuals and businesses must have greater access to information on themselves, and government must be opened up to others and to itself.

But what will happen when citizens realize how much data is held on them by government? The implications of this movement of data online are not discussed in the book. However, there are complex issues regarding government access to data that should be confidential, and risks for government custodians of the data should they be hacked or inadvertently leak the

3 Initial work in this area has been started by McConnell *et al.* (2013).

information. In contrast, government could make greater use of the vast troves of data at their disposal. Academics would no doubt be enthralled to gain access to these data for research. Would mining these data—with appropriate safeguards—allow for better policy-making? Exploring the impacts of tax credits using firm-level data could lead to greater insights on what policies work to improve business productivity, for instance.

An aspect not explored in depth by the book is the impact of social media within government. It would seem that such technologies could be further exploited to remove the duplication of roles across departments. For example, having a small group of individuals follow and report on a subject of international negotiations on behalf of an entire government, and disseminating information through Web 2.0 technologies, would seem to be more efficient than having such a group in each individual department in its own silo.

The digital era may also lead to radical changes in the services provided, either by the private sector or by public institutions. A topic currently attracting attention is the possibility of universities facing increased competition from massive open online courses (MOOCs) whereby students anywhere in the world can enroll in online courses developed anywhere else in the world (The Economist, 2013). Although the courses themselves might be free, a business model could be developed by charging the students to take an exam and get certified. With such massive economies of scale, productivity in the education sector could be drastically improved.

The Impact of Government Policies on Economy-wide Productivity

Economists have long complained about niche policies inhibiting the effectiveness of broad-based policies: it is better to broaden the base of a tax rather than have specific tax credits because of the distortions induced in private-sector choices for investment or employment. Sometimes, additional costs are included, such as the administrative costs of government programs supporting business-sector R&D (Lester, 2012). But the measurement of government productivity means further costs of such policies can be uncovered. One of the targets of the authors' efforts to measure productivity is the administration of the tax system. The United Kingdom introduced a number of tax credits aimed at the poor during the period reviewed by the authors, but these led to chaos in tax administration, and a decline in its productivity. Tax exemptions are complex and require much greater inputs into monitoring, recording and auditing activity; hence, they lower productivity. The cost of proposals for specific tax exemptions in lowering government productivity should be included in any cost-benefit analysis.

What Are the Broader Implications of Measuring Government Productivity?

The authors examine government productivity in considerable detail, but there are broader issues from measuring government productivity.

Who Has the Imperative to Change Government Productivity?

The incentive structure faced by those in government limits their interest in improving productivity. Efforts to improve productivity may be resisted by bureaucrats who could see the importance of their expertise diminished or, indeed, their jobs disappear. Others may feel that they attain greater status by the size of their staff rather than by the effectiveness with which it is managed. Furthermore, managers and politicians may limit the imperative for action since change can be both controversial and risky. So, despite the potential to improve the productivity of government services, an interesting question is from where do the pressures to introduce change come in government? Without measurement of productivity, any stagnation in service provision may not be apparent although large failures may generate sufficient political problems to encourage change. Do significant policy changes require crises or initiatives from the top? For example, the top-down demand for the digitization of government services seems to have been critical to move government services online in the United kingdom.

One prospect is the increased use of social media if the public can obtain access to data. Stories abound on the impact that social media is having on politicians in China (Tkacheva *et al.*, 2013), so could a similar effect work with government services in developed economies? Maintaining the centrality of "customers" to hospitals and schools through providing data could limit the potential of disastrous effects such as the recent scandals of premature deaths in hospitals in the United Kingdom. The expectations of citizens are increasing, and with knowledge there would be additional impetus for change. The question then becomes whether government moves ahead of these changes that are probably inevitable, or whether it is dragged along afterwards?

Political Control

A wider concern with the agenda put forth by Dunleavy and Carrera is their light treatment of political control and the doctrine of ministerial accountability. Government services remain services that are mandated by the state and at least partly funded either by the taxpayer or by levies mandated by the state. Although placing responsibility for services in an arms-length agency removes direct political control, the decision to delegate responsibility remains a political act. The inevitability of political oversight remains, so the hopes for dramatic experimentation and innovation in service delivery between bureaucrats and the public without additional mediation by the political system may be misplaced.

Donald Savoie (2003:147) has pointed out that "Public servants operate in a highly politicized atmosphere. Government managers do not enjoy the same kind of privacy or private space that their private-sector counterparts do. Any decision can become the subject of a public debate, a question in Parliament, or a ten-second clip on the television news. The managers who decided, for example, to replace windows at the Department of External Affairs [in Canada] never expected that their action would receive intense media coverage, give rise to questions in Parliament, and move the minister for government services to declare that the decision was 'stupid' and that he 'wanted a full explanation' since he had never been made aware of the file." Political control—and its implications in setting incentives for bureaucrats—will remain.

In addition, and although the authors hold out great hopes for a move to a citizen-based, services-based or needs-based foundation of organization to improve government performance, there will be an inherent or even necessary tension between the state and citizens in the provision of some government services. Ultimately, the power of the state is coercive. Although providing welfare payments for the unemployed is a valuable government service, there may also be a valid concern that those on welfare be encouraged to obtain work as soon as possible, as in the Danish workfare program. In these cases, governments providing what "customers" want may not be what the public at large and their democratically-elected representatives have in mind, regardless of the impact on productivity.

The Role of Productivity Measurement as a Performance Target

One of the roles that monitoring government productivity can play according to Atkinson (2005) was as a performance target. Can productivity also play a wider role as a guiding principle for the organization of government services? Can measuring government productivity break the trade-off between accountability and efficiency? The answers are probably at least a partial yes.

To shed light on these questions, one can turn to the history of how government administration has been organized. Traditionally, government bureaucracies have been hierarchical systems of control, as initially described in 1918 by Max Weber (Weber, 1946). Policy is set at the top through political control, and bureaucrats then operate within a system of rules and regulations. Although the dividing line is murky in practice, the administration of policy should be distinct from the setting of policy. Firm lines of accountability are set, but at the cost of the stultifying effects on bureaucracy, which lower productivity.

An attempt to soften the stark contrast between bureaucracy and markets was the introduction of New Public Management (NPM), which held out the prospect that market-oriented management of the public sector would improve productivity. OECD (2010) summarized the NPM approach as decentralization; management by objectives; contracting out; competition within government; and consumer orientation. Consequently, large bureaucracies were broken into smaller agencies and other activities were outsourced to private firms. NPM tried to increase the efficiency of providing government services, but lines of accountability were less distinct.

Throughout the book, the authors criticize the management philosophy of NPM, as one of them, Patrick Dunleavy, is a well-known opponent (see, Dunleavy *et al.*, 2005, for example). Many arguments against NPM appear valid. The book criticizes facets of NPM such as the outsourcing of IT, which appears to have been badly managed. The introduction of NPM led to the proliferation of agencies with their own accounting, human resource and IT systems that probably inhibited scale economies from being exploited. This is an aspect that measuring government productivity would be well placed to capture. The authors quote an estimate from Gershon (2004) that cost savings of £20 billion over 4 years could be obtained in the United Kingdom from shifting to smarter procurement across the 270 governmental agencies.

This critique of NPM could have been explained in the book in a more structured way. From an economists' perspective, it is not quite clear why services that are provided by the government—because they were underprovided by the market—would necessarily benefit from increased private-market incentives. Furthermore, since Coase (1937) we have known that transaction costs have important implications for the organization of firms, and these costs seem rife in the provision of government services. These transaction costs imply, for example, that there is an inability to write comprehensive contracts that would lead to private-sector firms under-providing those elements not covered by contracts (see discussion in Hart, 2003, for example). Finally, the vast scale of government operations suggests that fixed costs are important. Large fixed costs with a limited number of firms that could undertake such operations together suggest large barriers to entry and an oligopolistic structure. Because of these failures, and evidenced by the notable failures discussed in the book, a new search should be underway for a guiding principle for government.

So can measuring government productivity help? Pfiffner (2004) outlines three questions that the modern state must answer:

1) What shall control policy?
2) Who shall implement policies?
3) How will performance be measured?

NPM largely answered the first and second questions through delegating power and employment to firms in the private sector in order to increase the efficiency of service provision. This approach, Dunleavy would argue, has exceeded its limit and so more activities need to be brought back within the state.

The third question is where the measurement of government output and productivity raises tantalizing prospects. Traditional bureaucratic control has concentrated on measuring inputs as a means of measuring performance. As summarized in Pfiffner (2004), 'line-item budgeting' was developed to carefully control for inputs used in government programs. Over time, this was superseded by performance budgeting with a focus on government functions. However, this approach then tended to focus on outcomes, and outcomes are a result not only of government efforts, but also of the efforts of individuals. NPM did introduce a greater focus on outputs, but these outputs tended to be too simple and, consequently, most appropriate for services that were easily reported and monitored, such as janitorial services.

This book highlights how even incorporating measures of output could yield insights into the performance of government agencies and the use of resources.[4] Looking at the number of passports issued by the passport office is a simple measure, but it would at least keep the passport office concentrated on issuing passports. Although bureaucrats may argue that output measures cannot fully capture the breadth of their work, it seems that this relatively objective measure introduces transparency and shifts the burden of proof onto government agencies to justify their performance. On the basis of what gets measured gets done, measuring the productivity of government services would be an important step in improving the performance of the state.

Conclusion

The book raises many challenging questions. However, the core of the book is the emphasis on assessing and measuring the productivity of government services, and the role of IT in improving them. So can government services be measured, and is the emphasis that the authors based on IT appropriate?

In many cases, government services can be measured, and the book makes a compelling case for measuring many of the services provided by government. Since these make up a sizeable part of GDP, citizens' well-being will increase. For those working in the central agencies of government, such as treasuries or cabinet offices, it may be harder to sum up policy advice into a single service. However, shedding light on all the wider activities provided by government, ranging from providing employment insurance to supporting research in universities, would encourage greater attention to improving these public services. In particular, taxpayers increasingly expect to have greater information on the performance of publicly-funded organizations, including for particular institutions such as 'their' hospital or university.

As for the role of IT, theories of long-term economic growth argue that innovation is critical. Innovation is driven by ideas, from new concepts invented by laboratory researchers to new practices developed by workers on the factory floor—all from the intentional actions of people responding to incentives. Innovation is often embodied in or facilitated by IT, and the willingness of organizations to not only invest in IT but also to reorganize their business processes allows them to make the most of innovation developed by individuals and teams. However,

4 The *Atkinson Review* noted that data generated to improve management performance in government services may not always be compatible with data to measure long-term productivity trends. As discussed further in Neuburger and Caplan (1998), data aimed at improving management performance need to be precise, transparent, simple, and not subject to manipulation. There was no requirement for them to be stable, and they could be highly selective. In contrast, data for monitoring productivity can be highly complex, but need to be consistent over time and cover the services provided comprehensively.

the core of innovation remains people's ideas, and so the crux for government will be the encouragement of and receptiveness to ideas, if its productivity is to be improved.

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