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

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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:

$$(1)\ \Delta \ln MFP_t = \Delta \ln Y_t - (\bar{v}_{L,t}\Delta \ln L_t + \bar{v}_{K,t}\Delta \ln K_t)$$

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.

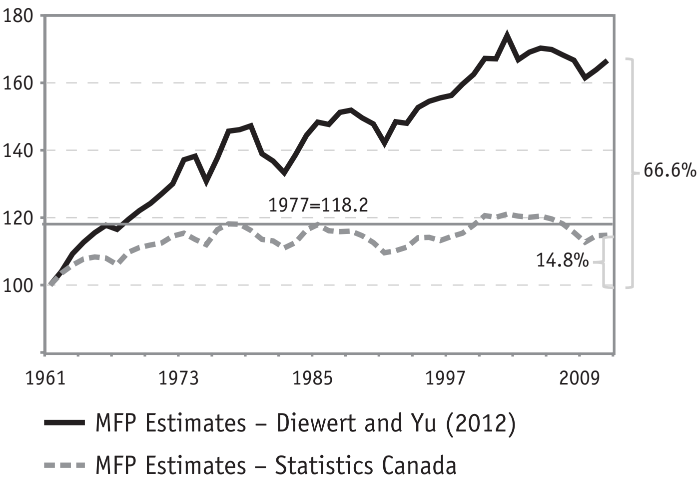
In this article, we investigate if alternative methodological assumptions matter for MFP growth estimates in Canada, and if so, how they affect the estimates in the United States relative to those in Canada. In particular, we go to great lengths to develop the necessary datasets for three alternative 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)

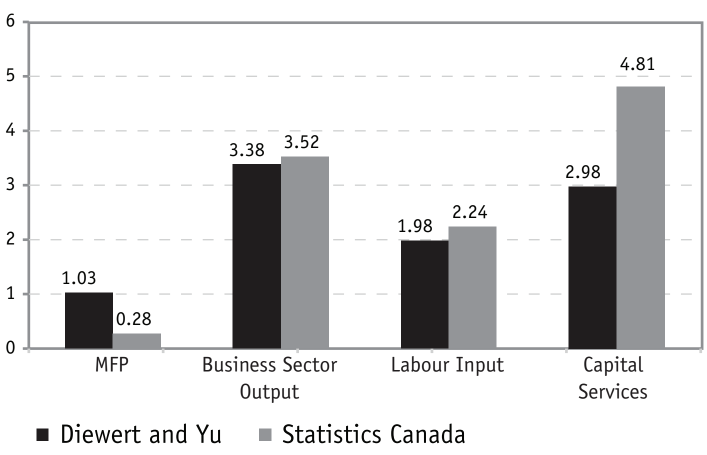


Source: Diewert and Yu (2012).

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

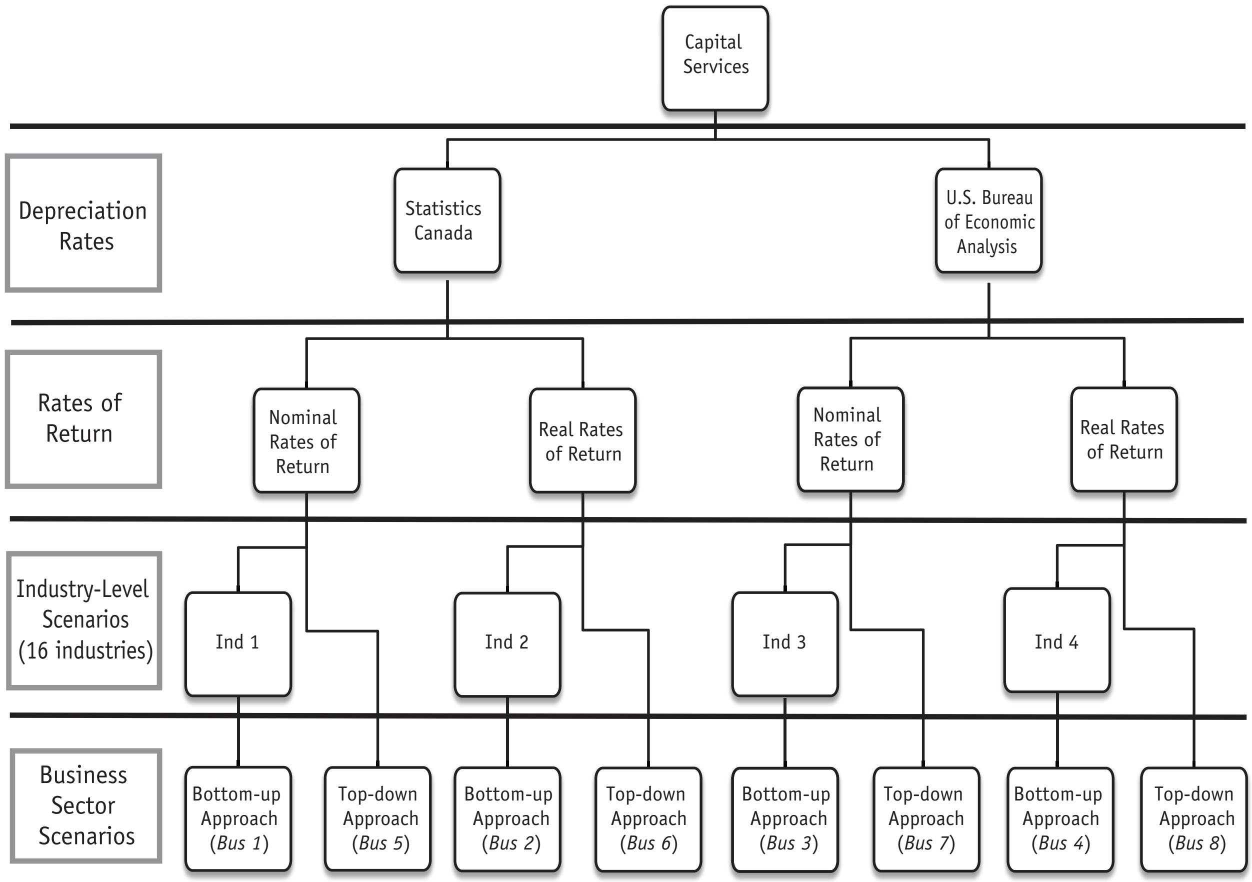
Ind2 Using *Statistics Canada asset depreciation rates* and assuming the *real* rates of return to capital are the same across asset types at the industry level

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)

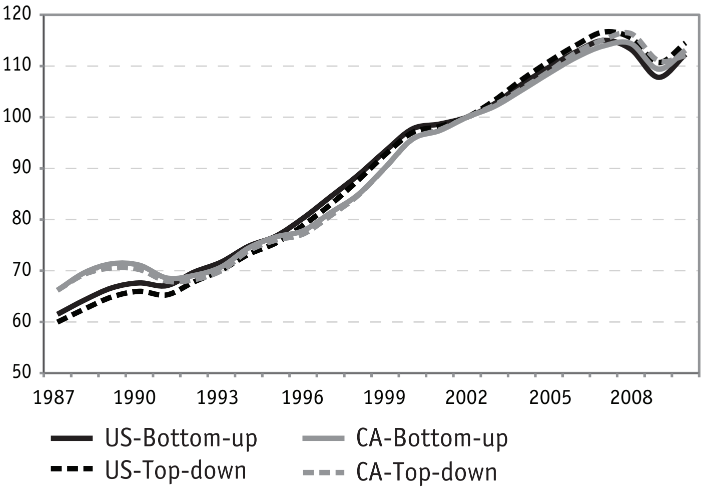
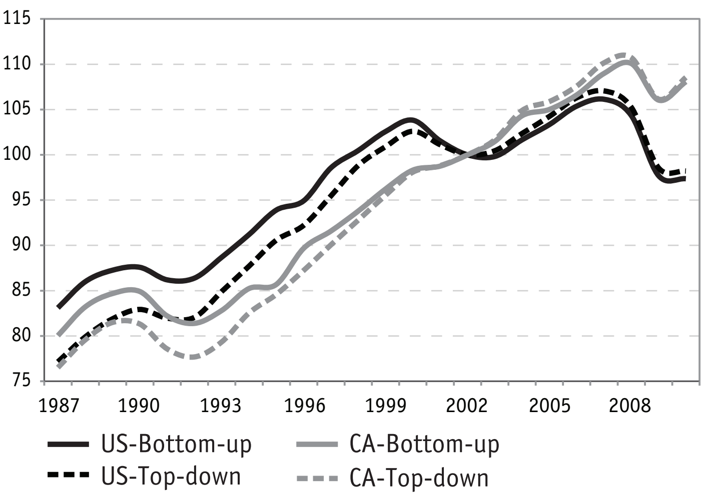


Chart 4
Labour Services in the Canadian and U.S. Business Sector, 1987-2010
(2002=100)



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

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)

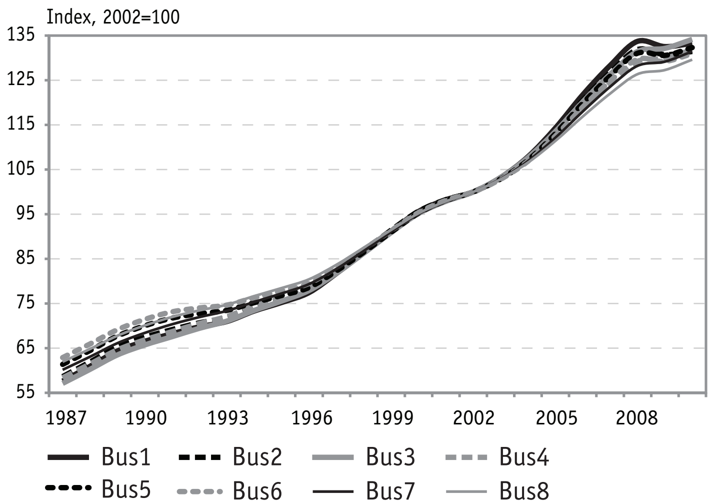
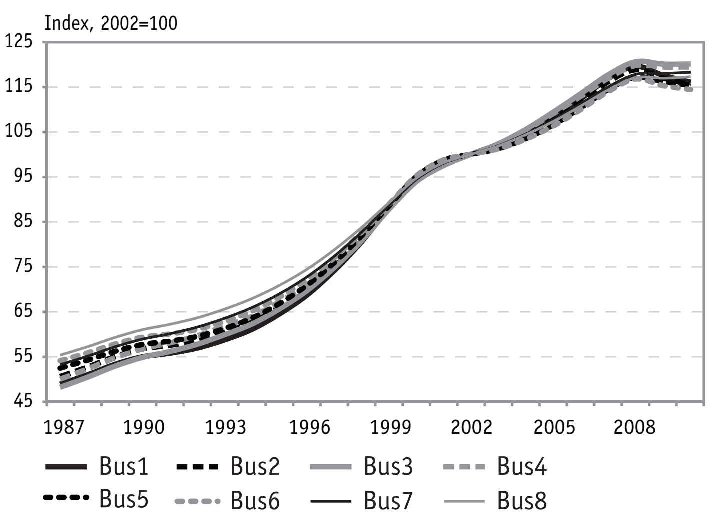


Chart 6

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.

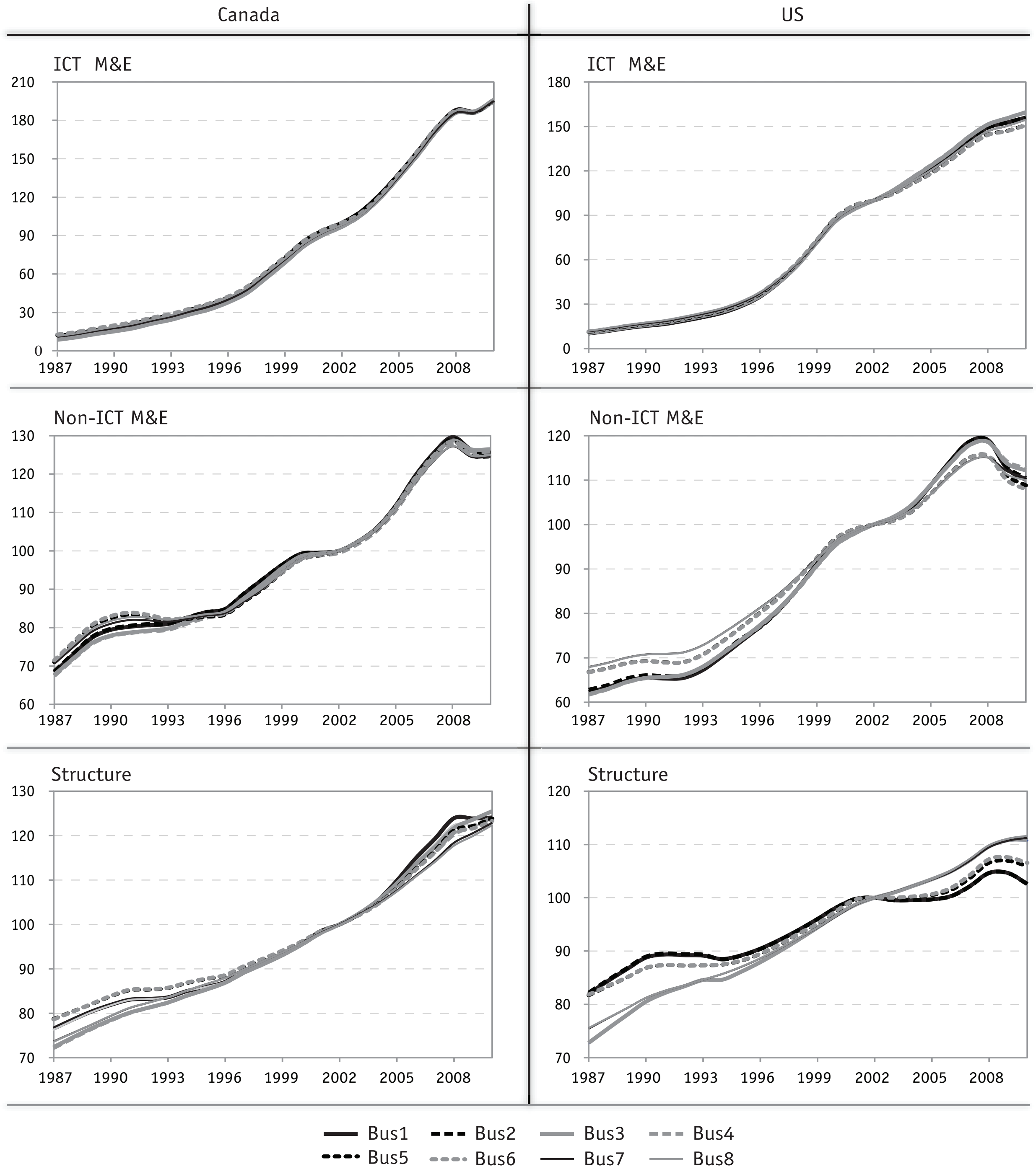
15 MFP growth rate estimates for the two sub-periods are reported in Tables A2 and A3 in Appendix.

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)

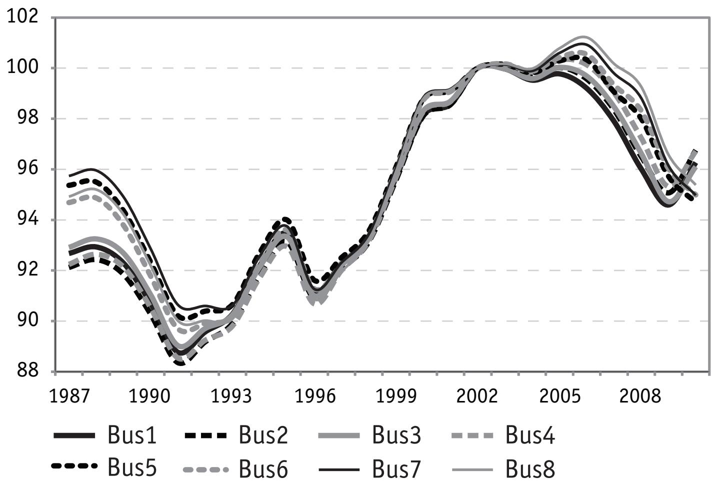
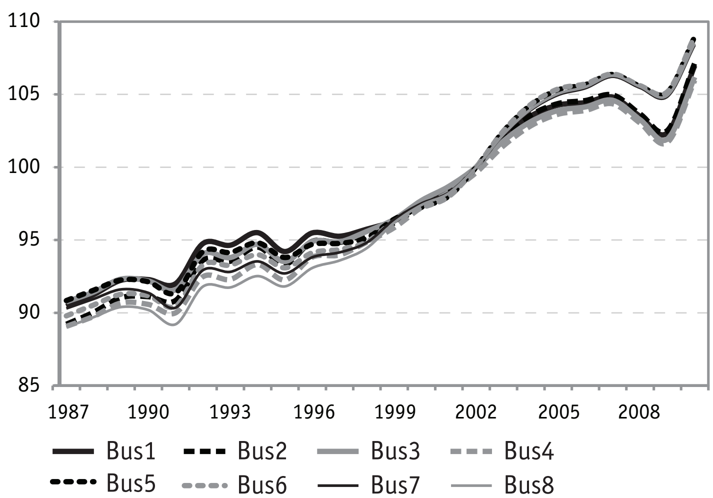


Chart 9
MFP in the U.S. Business Sector, 1987-2010
(2002=100)



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.

Reference

Baldwin, John and Wulong Gu (2013) "Multifactor Productivity Measurement at Statistics Canada," Statistics Canada, Catalogue no. 15-206-X No. 31.

Diewert, Erwin and Emily Yu (2012) "New Estimates of Real Income and Multifactor Productivity Growth for the Canadian Business Sector, 1961-2011," *International Productivity Monitor*, No. 24, Fall, pp. 27-48.

Fleck, Susan, Steven Rosenthal, Matthew Russell, Erich H. Strassner, and Lisa Usher (2012), "A Prototype BEA/BLS Industry-Level Production Account for the United States," research paper Presented at 2nd World KLEMS Conference Harvard University Cambridge, Massachusetts August 9-10, 2012

Gellatly, Guy, Marc Tanguay, and Beiling Yan (2002) "An Alternative Methodology for Estimating Economic Depreciation: New Results Using a Survival Model," in *Productivity Growth in Canada*, Catalogue no. 15-204-XPE, Statistics Canada.

Gu, Wulong (2012) "Estimating Capital Input for Measuring Business Sector Multifactor Productivity Growth in Canada: Response to Diewert and Yu," *International Productivity Monitor*, No. 24, Fall, pp. 49-62.

Jorgenson, Dale W. (2012) "The World KLEMS Initiative," *International Productivity Monitor*, No. 24, Fall, pp. 5-19.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni (1987) *Productivity and U.S. Economic Growth* (Cambridge MA: Harvard University Press).

Patry, André (2007) "Economic Depreciation and Retirement of Canadian Assets: A Comprehensive Empirical Study," Catalogue no. 15-549-XIE, Statistics Canada.

Statistics Canada (2007) "Depreciation Rates for the Productivity Accounts," *The Canadian Productivity Review*, Statistics Canada, Catalogue no. 15-206-XIE2007005 (Ottawa: Statistics Canada).

Tang, Jianmin, Someshwar Rao, and Min Li (2010) "Sensitivity of Capital Stock and Multifactor Productivity Estimates to Depreciation Assumptions: A Canada-U.S. Comparison," *International Productivity Monitor*, No. 20, Fall, pp. 22-47.

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.