Accounting for Slower Productivity Growth in the Canadian Business Sector after 2000: The Role of Capital Measurement Issues

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Abstract

Labour productivity growth and multifactor productivity (MFP) growth slowed in Canada and other advanced economies after 2000. This article focuses on the issues that are associated with measurement of capital and examines the roles of intangible capital, natural capital, public infrastructure capital and capacity utilization in explaining slower productivity growth. To do that, the article presents an extended growth accounting framework that is used to examine the role of the different types of capital in labour and multifactor productivity growth. It finds that about one quarter of the decline in multifactor productivity growth in the Canadian business sector between 1980-2000 and 2000-2015 was due to an increase in the use of produced capital required to extract natural resources in the oil and gas and mining sector and a decline in the utilization of capital in the manufacturing sector. The decline in labour and multifactor productivity growth after 2000 is not related to intangible capital and public infrastructure capital.

Labour productivity growth and multifactor productivity (MFP) growth slowed in the Canadian business sector after 2000 (Baldwin and Willox, 2016; Almon and Tang, 2011; Rao, Sharpe and Smith, 2005).[2] Labour productivity (value added per hour

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2 While the productivity growth slowdown is widespread in advanced economies, the timing of the slowdown differs. In the United States, the productivity growth slowdown occurred in 2004 after the rapid productivity growth in the 1990s and early 2000s (Byrne *et al.*, 2016; and Cette *et al.*, 2016). For many European countries, the slowdown occurred in the mid-1990s (Cette *et al.* 2016; OECD, 2016). For Canada, the productivity growth slowdown occurred after 2000 (Baldwin and Willox, 2016).

worked) growth in the Canadian business sector declined from 1.7 per cent per year in 1980-2000 to 1.0 per cent per year in 2000-2015.[3] MFP growth declined from 0.4 per cent per year to -0.2 per cent per year between the 1980-2000 and 2000-2015 periods. This recent slowdown in productivity growth also occurred in the United States and other developed economies (Byrne, Fernald, and Reinsdorf, 2016; OECD, 2015).

Previous studies have identified a number of potential explanations for this development. They include a slower pace technological progress, a slowdown in the diffusion of innovation, a decline in competitive intensity, a fall in business dynamism, and the misallocation of resources due to the sharp decline in real interest rates (Baily and Montalbano, 2016; Cette, Fernald and Mojon, 2016; OECD, 2015; Murray, 2017 and 2018).

A number of measurement challenges have also been suggested as potential explanations. They include the measurement of gross domestic product and knowledge capital in a digital economy, the measurement of natural resource capital in the resource extraction sectors, the effect of public infrastructure capital, and the effect of cyclical fluctuations in the utilization of capital (Ahmad and Schreyer, 2016; Byrne *et al.*, 2016, Rao *et al.*, 2005).

This article focuses on the issues that are associated with measurement of capital and examines the roles of intangible capital, natural capital, public infrastructure capital and capacity utilization for slower productivity growth in Canada after 2000. First, the article extends the asset coverage to include intangible capital not already included in the System of National Accounts (SNA), natural capital and public infrastructure capital so as to develop a more comprehensive measure of capital flows and services and to better understand the role of investment in output and labour productivity growth. Intangible knowledge capital such as innovative property (scientific and non-scientific R&D, design, product development, mineral exploration and the production of the artistic originals), economic competencies (firm-specific investment in brand equity, human and organizational capital), and computerized information (software and databases) has been identified as an important source of output growth and productivity growth. But growth accounting and national accounts currently only include R&D, software and mineral exploration in measured capital input. Natural capital represents an important input to the mining and oil and gas extraction sector, but it is excluded in the measure of capital input to the sector. Public infrastructure capital contributes to output and productivity growth of the business sector, but is often not included in the growth accounts for this sector.

While expanding the asset coverage to include intangible capital, natural capital and public infrastructure capital will affect MFP growth, the extent to which it accounts for the slowdown in labour productivity and multifactor productivity growth is not known.

Second, the article focuses on the role of short-run changes in the utilization of capital input for the slower MFP growth in manufacturing after 2000. The utilization of capital declined in the Canadian manufacturing sector in the early

3 The weak productivity growth in the business sector in the 2000-2015 period continued in 2016 when labour productivity increased only 0.6 per cent, while multifactor productivity increased 0.1 per cent. In 2017, because of the strong performance of the Canadian economy, labour productivity growth picked up to 2.2 per cent.

2000s resulting from slower export and output growth due to the appreciation of Canadian dollars and slower growth in the United States. The decline in MFP growth at least in manufacturing after 2000 is found to be partly due to this decline in the utilization of capital in that period (Baldwin, Gu, and Yan, 2013). While various procedures exist to examine the effect of changes in capacity utilization on MFP growth, they are often ad hoc. To address that gap, a new measure of capacity utilization has been developed that can be used to adjust MFP growth for changes in the utilization of capital input (Gu and Wang, 2013).

The methodologies that can be used to address those capital measurement challenges have been developed in previous studies in Canada and other countries. A contribution of this article is to use those methodologies to extend the estimates to more recent years and to ask to what extent those capital measurement issues account for the slower labour and MFP growth in Canada after 2000.

In addition to the input measurement issues examined, there are issues associated with the measurement of service sector output, the measurement of output from new goods and services, the measurement of information and communication equipment prices that could be important for explaining slower productivity growth in the recent years (Byrne and Corrado, 2017). The measurement of "free" digital services (e.g. social media, and search engines) is also mentioned as a factor for the slower productivity growth (Varian, 2011; Brynjolfsson and Oh, 2012; Nakamura, Samuels and Soloveichik, 2016). The output and productivity growth extended to include the benefit of the digital services would have increased faster in the recent years. But such benefit is the output of nonmarket production and is outside the production boundary of the national accounts.

The article is organized as follows. The first section begins with a decomposition of MFP growth into the contributions by industry to identify the industries that are responsible for the slower MFP growth.[4] Section 2 extends the asset coverage to include intangible capital not currently included in the SNA. Section 3 discusses the role of public infrastructure capital. Section 4 examines the effect of natural capital. Section 5 takes into account changes in capacity utilization in MFP growth in the manufacturing sector. Section 6 summarizes the roles of intangible capital, public infrastructure capital, natural capital and capacity utilization for the slower MFP growth in the Canadian business sector after 2000. Section 7 concludes.

Aggregate and Industry Productivity Growth in Canada

This section presents the recent trends in labour productivity growth and its main components: investment in capital, labour compositional changes arising from investment in human capital, and MFP growth at the aggregate business sector level. It shows that the decline in aggregate labour productivity growth after 2000 is largely attributed to a decline in MFP growth. The section also decomposes aggregate MFP growth into contributions of individual industries and identifies the industries that contributed to this decline in multifactor productivity growth after 2000. The data are taken from the productivity accounts of Statistics Canada.

The productivity accounts of Statistics

4 Calver and Murray (2016) provided another decomposition of MFP growth by industry and province.

Table 1: Sources of Output and Labour Productivity Growth in the Business Sector in Canada, 1980-2000 and 2000-2015 (Average Annual Compound Rate of Change)

	1980-2000	2000-2015	2000-2015 less 1980-2000
Growth in real value-added	3.18	1.84	-1.35
Growth in hours worked	1.48	0.88	-0.59
Labour productivity growth	1.70	0.95	-0.75
Contributions to labour productivity growth from			
Capital deepening	0.89	0.90	0.01
Labour composition	0.38	0.23	-0.15
Multifactor productivity growth	0.43	-0.18	-0.61

Source: Authors calculation from CANSIM Table 383-0021, Statistics Canada.

Canada follow the framework pioneered by Jorgenson (1963), Jorgenson and Griliches (1967), Jorgenson, Gollop and Fraumeni (1987), Jorgenson, Ho and Stiroh (2005), and Schreyer (2001) who have developed integrated industry and total economy growth accounts.[5] Industry-level productivity growth is estimated making use of detailed data on output and inputs, and aggregate productivity growth is estimated making use of the industry-level data. Industry productivity accounts and aggregate productivity accounts are fully integrated and multifactor productivity growth at the aggregate level and the industry level are related to one another through the Domar aggregation (Domar, 1961).

MFP growth in the productivity accounts is defined as output growth that is not accounted for by the growth of capital, labour and intermediate inputs. To estimate MFP growth, the user cost and volume index of capital input are estimated first. The user cost of capital is equal to the sum of the rate of return to capital, depreciation and capital gains adjusted for the effects of tax treatments.[6]

Aggregate Productivity Growth in the Total Business Sector

Table 1 presents the trend in output and productivity growth in the business sector for the 1980-2000 and the 2000-2015 periods. The first three lines in the table decompose output growth into the contribution from growth in hours worked and the contribution from growth in labour productivity. The last three lines decompose labour productivity growth into its three main components: capital deepening, changes in labour composition, and MFP. Capital deepening captures the effect of investment and increases in capital intensity on labour productivity growth. Changes in labour composition capture the effect of investment in education and training on labour productivity growth. A residual called MFP growth includes the effect of disembodied technological change and organizational innovation, economies of scale, and short-term changes in capacity utilization.

5 The framework is also used to construct the World KLEMS productivity accounts for a large number of countries (Timmer, Inklaar and O'Mahony, 2010 and 2011; Jorgenson, 2012 and 2017).

6 For discussion of recent changes Statistics Canada has made to the measurement of MFP, see Gu (2018).

Output growth in the business sector declined from 3.2 per cent per year in 1980-2000 to 1.8 per cent in 2000-2015. This decline in output growth after 2000 reflects both a decline in labour productivity growth and a decline in the growth of hours worked.

The decline in labour productivity growth from 1.7 per cent per year in 1980-2000 to 1.0 per cent per year in 2000-2015 was mainly due to a decline in MFP growth. MFP growth declined 0.6 percentage points from 0.4 per cent per year in 1980-2000 to -0.2 per cent in 2000-2015. There was little change in the contributions of capital deepening effects. The labour composition effect declined 0.2 percentage points from 0.4 per cent to 0.2 per cent between periods.

Industry Contributions to MFP Growth

This section quantifies the contributions of industries to the decline in MFP growth in the business sector after 2000. Table 2 and Chart 1 present MFP growth based on value added by industry. Table 3 presents the industry contributions to aggregate MFP growth. The contribution of an industry to aggregate MFP growth is calculated as industry MFP growth multiplied by the industry share of aggregate capital and labour input costs.

For the pre-2000 period, MFP growth exceeded 2 per cent per year in agriculture, forestry, fishing and hunting; manufacturing; and wholesale trade (Table 2). Those industries accounted for almost all MFP growth in the business sector for that period (Table 3). The rapid MFP growth in manufacturing, which made by far the largest contribution to business sector multifactor productivity growth (0.50 percentage points per year) was a result of the trend towards trade liberalization that led to increased competition, innovation and adoption of advanced manufacturing technologies (Trefler, 2004; Baldwin and Gu, 2004).

After 2000, multifactor productivity growth slowed and became negative at the business sector level and in certain goods-producing industries, especially in mining and oil and gas extraction. The service industries that invested heavily in information and communication technologies maintained positive multifactor productivity growth and in general did not show a decline in multifactor productivity growth. Those service industries include the retail trade, information and cultural industries, and finance, insurance and real estate industries.

MFP increased at 0.4 per cent per year in the business sector in 1980-2000. It then fell 0.2 per cent per year in 2000-2015, a 0.6 percentage point decline between periods. This decline in aggregate MFP growth after 2000 was mostly due to a decline in MFP in two industries: manufacturing and mining and oil and gas extraction. The decline in multifactor productivity growth in the manufacturing sector accounted for a 0.4 percentage point decline in aggregate MFP growth, while the decline in the mining, oil and gas extraction industry accounted for another 0.4 percentage point (Table 3).

The findings that manufacturing and mining and oil and gas extraction are largely responsible for the decline in aggregate MFP growth after 2000 point to a further investigation of potential issues in those industries. Those issues include the decline in the utilization of capital in the manufacturing industry and the incorporation of natural capital input in the measurement of MFP growth in the mining and oil and gas extraction sector. The rest of this article will examine those issues and the roles of intangible capital and public infrastructure capital in the decline of aggregate productivity growth after 2000.

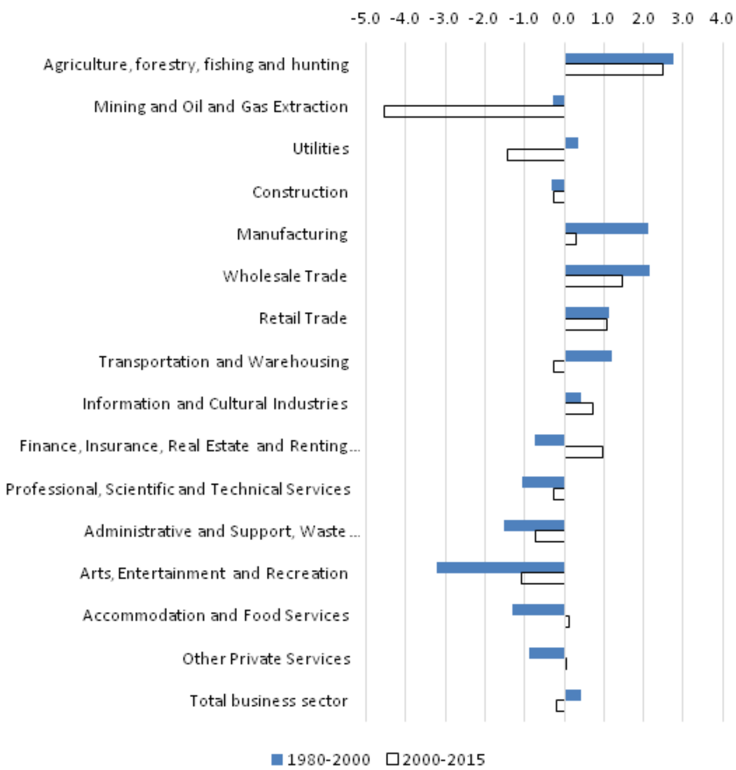
Table 2: Multifactor Productivity Growth by Industry, 1980-2000 and 2000-2015 (Average Annual Compound Rate of Change)

Industry	1980-2000	2000-2015	2000-2015 less 1980-2000
Agriculture, forestry, fishing and hunting	2.75	2.48	-0.26
Mining and Oil and Gas Extraction	-0.29	-4.56	-4.27
Utilities	0.33	-1.43	-1.76
Construction	-0.33	-0.26	0.07
Manufacturing	2.12	0.31	-1.81
Wholesale Trade	2.15	1.47	-0.68
Retail Trade	1.14	1.06	-0.08
Transportation and Warehousing	1.21	-0.26	-1.47
Information and Cultural Industries	0.43	0.71	0.28
Finance, Insurance, Real Estate and Renting and Leasing	-0.75	0.97	1.72
Professional, Scientific and Technical Services	-1.06	-0.26	0.80
Administrative and Support, Waste Management and Remediation Services	-1.54	-0.74	0.80
Arts, Entertainment and Recreation	-3.22	-1.09	2.13
Accommodation and Food Services	-1.31	0.12	1.43
Other Private Services	-0.88	0.06	0.94
Total Business Sector	0.43	-0.18	-0.61

Note. Multifactor productivity growth is based on value added.

Source: Authors calculation from CANSIM Table 383-0021, Statistics Canada.

Chart 1: Multifactor Productivity Growth by Industry (Average Annual Compound Rate of Change), 1980-2000 and 2000-2015



Source: Authors calculation from CANSIM table 383-0021, Statistics Canada.

Table 3: Industry Contributions to Multifactor Productivity Growth in the Business Sector, 1980-2000 and 2000-2015 (Average Annual Percentage Point Change)

Industry	1980-2000	2000-2015	2000-2015 less 1980-2000
Agriculture, forestry, fishing and hunting	0.09	0.06	-0.03
Mining and Oil and Gas Extraction	-0.03	-0.43	-0.40
Utilities	0.01	-0.05	-0.06
Construction	-0.03	-0.02	0.01
Manufacturing	0.50	0.06	-0.44
Wholesale Trade	0.14	0.10	-0.03
Retail Trade	0.08	0.07	-0.01
Transportation and Warehousing	0.09	-0.02	-0.11
Information and Cultural Industries	0.02	0.03	0.01
Finance, Insurance, Real Estate and Renting and Leasing	-0.10	0.15	0.25
Professional, Scientific and Technical Services	-0.05	-0.02	0.03
Administrative and Support, Waste Management and Remediation Services	-0.03	-0.02	0.01
Arts, Entertainment and Recreation	-0.02	-0.01	0.01
Accommodation and Food Services	-0.04	0.00	0.04
Other Private Services	-0.04	0.00	0.04
Sum of Industry Contributions	0.61	-0.09	-0.70
Reallocation of Output	-0.18	-0.09	0.08
Total Business Sector	0.43	-0.18	-0.61

Source: Authors calculation from CANSIM Table 383-0021, Statistics Canada.

Intangible Capital and MFP Growth

MFP estimates are sensitive to the comprehensiveness of output and input measures. The definition of outputs and inputs are based on the National Account framework that is the foundation for the Productivity Program. Recent attention has been paid to the incomplete coverage of assets used for estimating capital input. In particular, it has been argued that a number of intangible assets exist that have not been appropriately taken into account in measuring the growth in capital. Intangible assets include computerized information (software and computerized databases), innovative property (scientific R&D and non-scientific R&D), and economic competencies (brand equity, training and organizational capital) (Corrado, Hulten and Sichel, 2009).

The multifactor productivity measures published by Statistics Canada and others only include a small portion of intangible assets — those related to R&D, mineral exploration and software which in 2015 represented only 28 percent of total intangible investment. Whether the inadequate coverage of intangibles has a deleterious effect on the multifactor productivity measure is difficult to judge without an empirical study — since reclassifying intermediate expenses to investments both affects the measured output and measured capital.

Baldwin *et al.* (2009, 2012) developed a more extensive measure of intangible capital than is currently used in the National Accounts and they extended the growth accounting to include intangible capital. To estimate investment in intangibles, Baldwin *et al.* followed the method that is used to capitalize intangibles such as R&D and software in the national accounts and

Table 4: Decomposition of Labour Productivity Growth With Intangibles in the Canadian Business Sector, 1980-2000 and 2000-2015 (Average Annual Compound Rate of Change)

Industry	1980-2000	2000-2015	2000-2015 less 1980-2000
Including SNA Intangibles			
Value Added Growth	3.18	1.84	-1.35
Labour Productivity Growth	1.70	0.95	-0.75
Contributions from:			
Capital Deepening	0.89	0.90	0.01
Tangibles	0.69	0.79	0.11
Intangibles	0.20	0.11	-0.10
Labour Composition	0.38	0.23	-0.15
Multifactor Productivity Growth	0.43	-0.18	-0.61
Including All Intangibles			
Value Added Growth	3.30	1.85	-1.45
Labour Productivity Growth	1.82	0.97	-0.85
Contributions from:			
Capital Deepening	0.91	0.95	0.04
Tangibles	0.53	0.71	0.18
Intangibles	0.38	0.24	-0.14
Labour Composition	0.35	0.21	-0.14
Multifactor Productivity Growth	0.56	-0.19	-0.75

Source: Updated Table 3 in Baldwin, Gu and MacDonald (2012). Note: Intangibles already in the SNA are software, R&D and mineral exploration.

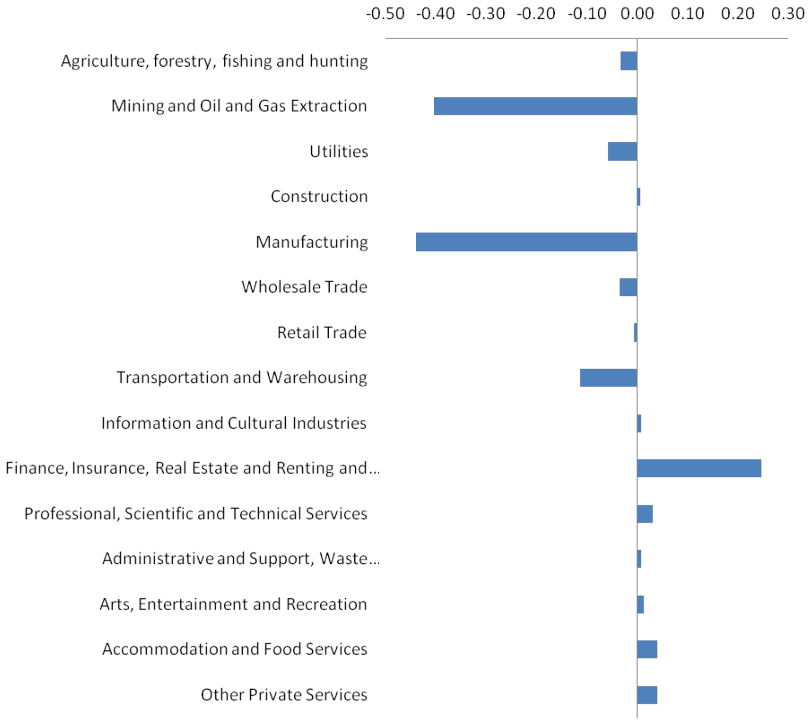
makes a distinction between purchased intangibles and own account intangibles. The purchased intangibles are re-classified from the intermediate inputs to investments in the industries that purchased intangibles. The own-account intangibles are directly added to the output of industries as they represent the intangible outputs in addition to the market outputs that are produced. Those two adjustments lead to an increase in the value added that equals the value of purchased and own-account intangibles.

Table 4 updates Baldwin *et al.* (2012) estimates to 2015. When expenditures on intangibles not already in the SNA are reclassified as investment from intermediate inputs and added to value added in the business sector, the real value added and labour productivity growth was higher in both 1980-2000 and 2000-2015 periods as the expenditures on intangibles increased faster than value added.

The upward adjustments to output and labour productivity growth were much larger in the 1980-2000 period than after 2000. As a result, incorporating intangibles not already in the SNA made the decline in aggregate labour productivity growth after 2000 even larger (from 0.75 points to 0.85 points). In other words, changes in intangible investment growth between the two periods do not explain the decline in aggregate labour productivity growth after 2000.

Expanding the asset coverage to include intangible capital not already in the SNA also affects the measurement of inputs and the decomposition of labour productivity growth into its three main components: capital deepening effect, labour composition effect and MFP growth. As Table 4 shows, when intangible capital not already included in the SNA is included, the effect of capital deepening (estimated as

Chart 2: **Industry Contributions to Decline in Average Annual Percentage Points Aggregate Multifactor Productivity Growth Between 1980-2000 and 2000-2015 (Percent per Year)**



Source: Derived from Table 3.

the share of capital costs in total input costs multiplied by the growth of capital-labour ratio) will increase as the share of capital costs becomes larger and the growth of the combined tangible and intangible input increases faster than tangible capital input. This lowers multifactor productivity growth estimates. The change to MFP growth estimates arising from those changes in labour productivity growth and its decomposition is found to increase MFP growth 0.13 points in the 1980-2000 period and to reduce MFP growth 0.01 points in the 2000-2015 period. Therefore the decline in multifactor productivity growth after 2000 became larger when intangibles not already included in the SNA are included in capital productivity measurement.

Natural Capital and MFP Growth in the Oil and Gas Extraction and Mining

MFP has been declining in the oil and gas extraction sector since the early 1990s and it has been declining in coal, metal ores and non-metallic mineral mining since the early 2000s.[7] The decline in MFP in those two sectors accounted for 0.4 percentage point, or more than half of the decline in multifactor productivity growth in the total business sector after 2000 (Table 3).

The existing MFP measure does not take into account the depletion of natural resource stock or the flow of natural resource capital. When natural capital is not included in capital input, the multifactor productivity measure is biased as the output includes the rent while the input does not include the flow of natural resource

7 MFP in Chart 2 is calculated based on value added. The MFP based on gross output shows a similar trend. The decline in MFP in the mining sector based on the standard growth accounting framework is also found in other countries including Australia, the United States and the Netherlands.

capital (or natural capital input) used to generate that output (Schreyer, 2012; Olewiler, 2017). Research in Australia and Netherlands shows that a substantial part of the decline in MFP in the oil and gas and mining sectors can be attributed to unmeasured natural capital input (Topps and Kuluys 2014; Veldhuizen and de Haan 2012; Australia Bureau of Statistics, 2014).[8] The resource extraction sectors in those countries involve more and more physical capital being applied for the extraction of natural resources due to an increase in the difficulties with which resources are being extracted. The growth in physical capital input is therefore higher than the growth in natural capital input, and the growth of the capital input estimate — that includes both natural and physical capital — will be slower than the growth in physical capital alone which boosts MFP growth. Multifactor productivity growth that accounts for the depletion of natural resource stock is much higher in Australia and Netherlands.

Schreyer (2012) presented an extended growth accounting framework for incorporating natural capital input in MFP measures for the oil and gas extraction and mining industry. In the extended framework, the quantity of natural capital input is equal to the volume index of resource extraction, while the user cost of natural capital input is the resource rent. The resource rent can be estimated residually. It is equal to the difference between the value of resource extracted and the costs of inputs other than natural capital where the user cost of physical capital is calculated using an exogenous rate of return.[9]

This procedure for estimating the volume index of natural capital input differs from the one for estimating the volume index of the other capital inputs. The volume index of capital input other than natural capital is not observed and is assumed to be proportional to capital stock. In contrast, the volume index of natural capital input is observed and is equal to the extraction of the natural resources.

Primary industries often use various types of natural resource capital such as oil and gas, coal, metal ores and non-metallic minerals in their production. Those different types of natural resource capital need to be aggregated to derive an aggregate measure of natural capital input. Similar to the procedure for aggregating produced capital across asset types, the weights for the aggregation should be based on the user costs of natural capital inputs.[10]

The resource rents by assets are often difficult to estimate as revenues and input costs must be allocated between multiple extraction activities for those firms that engage in the extraction of multiple natural resource assets. For this article, the value of natural resource assets is used for aggregation. This assumes that resource rent per dollar value of resource extracted is equalized across different types of resource assets. This is the procedure used by Statistics Netherlands in its measure of natural capital input and multifactor productivity for the mining sector (Veldhuizen and de Haan, 2012).

8 Australia Bureau of Statistics (2014) finds that the decline in the mining MFP is reduced significantly when natural capital input is included in the multifactor productivity measure, from -5.8 per cent per year to -2.2 per cent for the period from 2003-04 to 2012-13.

9 The resource rent is set equal to zero when negative. This occurs during the late 1980s and the early 1990s in Canada when natural resources prices were low.

10 Adams and Wang (2015) implemented such an approach using resource rent estimates for various types of natural capital inputs in the Canadian oil and gas extraction and mining industry.

Table 5: Multifactor Productivity Growth in the Oil and Gas Extraction Sector, 1980-2000 and 2000-2013 (Percentage Points Contribution or Per Cent per Year)

Industry	1980-2000	2000-2013	2000-2013 less 1980-2000
Real gross output growth	3.73	2.37	-1.36
Contributions from:			
Labour input	0.11	0.48	0.36
Produced capital input	1.65	3.00	1.35
Natural capital input	0.39	0.12	-0.28
Intermediate input	1.76	1.61	-0.15
Multifactor productivity growth	-0.19	-2.83	-2.64
Addendum			
Labour input growth	2.40	7.60	5.20
Produced capital input growth	3.87	6.72	2.85
Natural capital input growth	3.38	2.32	-1.05
Intermediate input growth	4.84	4.56	-0.28
Official Multifactor productivity growth (without natural capital)	-0.67	-3.63	-2.96

Source: Authors calculation from CANSIM Table 383-0032, Statistics Canada.

For Canada, the choice of weights for aggregation is found to have little effect on growth in estimated natural capital input.

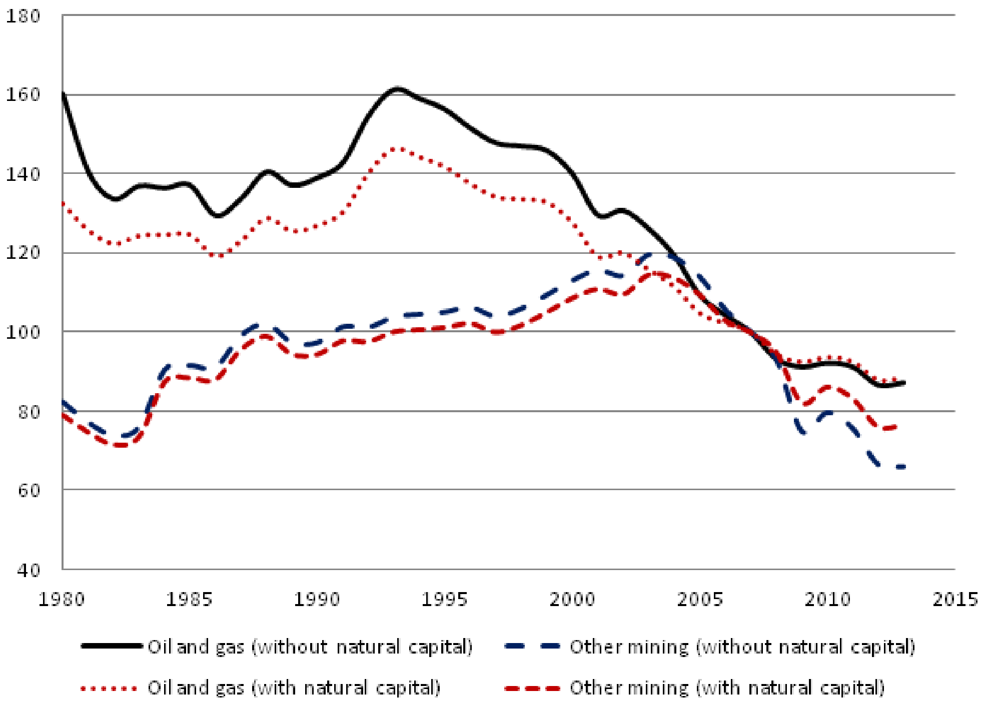
Table 5 and Chart 3 present the extended growth accounts for oil and gas extraction and mining. The data on gross output, capital, labour and intermediate inputs are taken from the productivity accounts of Statistics Canada (CANSIM Table 383-0032). The volume index of natural capital input is derived from the make tables of input-output accounts and is available for the period up to the most recent input/output table reference year 2013.

The growth in produced capital and labour is found to be faster than the growth in natural capital input in the Canadian oil and gas extraction over the period 1980 to 2013. This difference becomes larger in the post-2000 period. This reflects an increased use of produced capital and labour in the oil and gas extraction as oil and gas become increasingly more expensive to extract.

The extended growth accounts for oil and gas extraction in Table 5 also provide an assessment of the contribution of the natural capital input to economic growth. Over the 1980 to 2013 period, the largest contributors to output growth in the oil and gas extraction sector are the produced capital and intermediate inputs, followed by natural capital input and labour input. Natural capital input contributed 0.4 percentage points of 3.7 per cent annual growth in gross output in the oil and gas extraction in the period 1980 to 2000, and it contributed 0.1 percentage points of the 2.4 per cent annual growth in gross output in the 2000 to 2013 period.

The official MFP growth estimate, which is not corrected for the effect of natural capital, declined in the oil and gas extraction sector in both the 1980-2000 and the 2000-2013 periods. But the decline was much larger after 2000. It declined at 0.7 per cent per year in 1980-2000 period, and at 3.6 per cent in 2000-2013. This represents a 2.9 percentage point slowdown in MFP growth in the oil and gas sector between the two periods. When natural capital is included in the measurement of capital, the decline in MFP was smaller in both periods, and the slowdown in MFP growth after 2000 was also smaller (2.6 points versus 2.9 points).

Chart 3: Multifactor Productivity in the Oil and Gas and the Mining Sector, 1980-2013 (2007=100)



Source: Authors calculation from CANSIM table 383-0032 and the supply and use tables, Statistics Canada

The slowdown in MFP growth after 2000 in the oil and gas extraction sector is found to be partly due to unmeasured natural capital input in the sector.

Table 6 and Chart 3 present the growth accounts for the mining sector. MFP growth not adjusted for the effect of natural capital declined in the 2000-2013 period compared with the 1980-2000 period, from 1.6 per cent per year to -4.1 per cent, a 5.7 percentage point slowdown between the two periods. When natural capital input is included in the measure of total capital, the slowdown in MFP growth falls to 4.3 percentage points between the two periods from 1.6 per cent per year in 1980-2000 to -2.7 per cent in 2000-2013. The decline in MFP growth after 2000 in the mining sector is found to be partly due to unmeasured natural capital in the sector.

A better understanding of this decline in MFP growth requires a more explicit account of the decline in the quality of natural resources being extracted that is often cited as a main source of this decline. It also requires micro data on production activities of mines and estimates of productivity growth for various resource extraction activities, such as conventional and non-conventional oil extraction. Such data will provide a decomposition of the decline in MFP growth into contribution from productivity growth in different types of mines and in different types of resource extraction activities, and the contribution from changes in the composition of those various mine and resource extraction activities.

Public Infrastructure Capital and MFP Growth in the Business Sector

Public infrastructure capital (the nation's roads, bridges, sewer systems and water treatment systems, schools, and hospitals) constitutes a vital input for business sector

Table 6: Multifactor Productivity Growth in the Mining Sector (Except Oil and Gas Extraction), 1980-2000 and 2000-2013 (Average Annual Percentage Points or Percent Change)

Industry	1980-2000	2000-2013	2000-2013 less 1980-2000
Real gross output growth	0.97	1.07	0.10
Contributions:			
Labour input	-0.35	0.39	0.73
Produced physical capital input	-0.19	2.10	2.29
Natural capital input	-0.03	0.11	0.14
Intermediate input	-0.05	1.16	1.21
multifactor productivity growth	1.59	-2.68	-4.27
Addendum			
Labour input growth	-1.21	2.88	4.08
Produced capital input growth	-0.51	6.63	7.13
Natural capital input growth	1.06	0.92	-0.14
Intermediate input growth	-0.10	3.56	3.66
Official multifactor productivity growth (without natural capital)	1.58	-4.12	-5.70

Source: Authors calculation from CANSIM Table 383-0032, Statistics Canada.

production.[11] It contributes to productivity in the private business sector as it provides wider and deeper markets for output and employment and reduces the transportation and production costs.[12]

The contribution of public infrastructure capital to productivity growth can be examined using an extended growth accounting framework (Mas, 2006; Gu and Macdonald, 2009). The standard growth accounting framework employed for statistical agencies focuses on private sector inputs and outputs. The impact of public capital at present is subsumed in MFP.

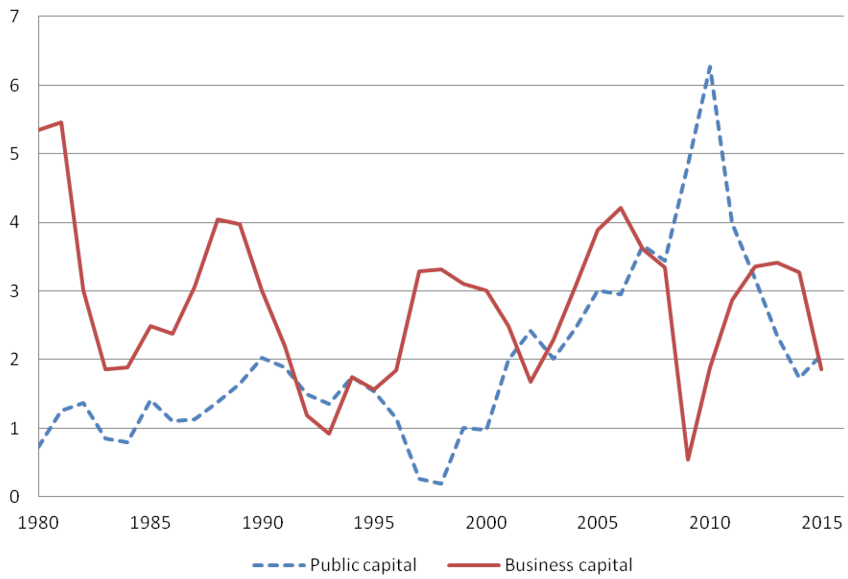
To explicitly analyse the contribution of public capital to productivity growth, MFP growth from the traditional growth accounting for the business sector is decomposed into the contribution from public capital and multifactor productivity growth net of the effect of public capital. This approach adopts the usual assumptions about constant returns to scale across private inputs and private inputs being paid their marginal revenue product. Public capital is assumed to affect output growth, but not the substitution between private capital and labour inputs.

Gu and Macdonald (2009) examined the contribution of public infrastructure capital to MFP growth in the business sector for the 1961-2006 period. The results from Gu and Macdonald (2009) are extended to 2015 in Table 7. The stock of public capital includes public capital stock of governments and public health and education sectors. The output elasticity of public capital is estimated assuming that the rate of return

11 This section examines the contribution of public infrastructure capital to labour productivity growth. The privately owned infrastructure is included in the business sector capital and its contribution to productivity growth is included in the capital deepening effect of the business sector.

12 Public infrastructure capital also benefits the household sector in terms of lower transportation costs and commute times. This article focuses on the benefits of infrastructure capital on the business sector production.

Chart 4: Public Infrastructure Capital Stock and Business Capital Stock, 1980-2015 (Annual Growth)



Source: Authors calculation from CANSIM table 383-0021 and the underlying investment data, Statistics Canada.

to public capital is equal to the after-tax return on capital in the business sector. The assumption is based on Macdonald (2008) who found that the rate of return to public capital is similar to the nominal after-tax return to capital in the business sector.

Chart 4 presents the growth of public infrastructure capital stock and business sector capital stock for the 1980 to 2015 period. During the 1980s and 1990s, the growth in public capital was slower than the growth in capital stock in the business sector as a period of cross-country highway expansion in the 1960s came to an end. In the late 2000s and early 2010s, the growth of public capital exceeded the growth in business sector capital, given the large investments in infrastructure from the government economic stimulus program during that period.

Table 7 presents the contribution of public capital to business sector productivity growth. Over the 1980-2000 period, public capital contributed 0.1 percentage points to average MFP growth in the business sector. During the period after 2000, the contribution of public capital to the business sector multifactor productivity growth picked up as a result of increased investment in public infrastructure, contributing 0.2 percentage points.

The results in Table 8 suggest that public capital contributed to an increase in MFP growth after 2000 as a result of increased investment in public capital in that period. This decline in aggregate MFP growth after 2000 is not due to the declining effect of public capital.

Capacity Utilization and MFP Growth in Manufacturing

MFP growth provides summary statistics that can help track technical progress. It is measured as output growth that is not accounted for by the growth in inputs. For such productivity residuals to provide an unbiased estimate of technical progress, all inputs should be corrected for the changes in their utilization. But productivity statistics published by Statistics Canada and most other statistical agencies do not correct for short-run variations in capacity utilization.

Table 7: Contributions of Public Infrastructure Capital to Multifactor Productivity Growth in the Business Sector, 1980-2000 and 2000-2015 (Percentage Points per Year)

	1980-2000	2000-2015	2000-2015 less 1980-2000
Official MFP growth	0.43	-0.18	-0.61
Public infrastructure capital contribution to MFP	0.08	0.23	0.15
MFP growth net of public infrastructure capital	0.35	-0.41	-0.76

Source: Authors calculation based on data from CANSIM Table 383-0021, Statistics Canada.

As such, the changes in MFP growth include the effect of changes in capacity utilization in the short run and do not necessarily measure technical progress. In this section, MFP growth is adjusted for short-term changes in capital utilization so as to examine the effect of capacity utilization on MFP growth.[13]

Correction for the effect of variations in capacity utilization is important when rates of capacity utilization change. In the early 2000s, Canada experienced a resource boom and an upward appreciation of the Canada-United States exchange rate. Based on micro-data on plant adjustments to pressures arising from changes in export markets and resulting declines in capacity utilization, Baldwin, Gu and Yan (2013) show that that the decline in the standard measure of multifactor productivity during the early part of the 2000s was partly due to the decline in capacity utilization.

Numerous studies have tried to adjust the multifactor productivity measure for capacity utilization. But as Berndt and Fuss (1986) noted, the adjustment is mostly ad hoc, because it lacks a theoretical framework. Gu and Wang (2013) developed a non-parametric procedure for such an adjustment based on the economic theory of production. Capacity utilization is measured based on the comparison of the ex post return with the ex ante expected return on capital. This is intuitively appealing, because changes in the ex post return on capital should mainly reflect the variation in capacity utilization. A higher level of unused capital and the resulting lower level of capacity utilization should be associated with a lower ex post rate of return, which is calculated on the actual level of capital. Similarly, a higher level of capacity utilization should be associated with a higher ex post rate of return on the actual level of capital.[14]

Table 8 presents MFP growth adjusted for the effect of capacity utilization in the manufacturing sector based on the Gu-Wang methodology. Changes in capacity utilization have little effect on MFP growth over the long run. But the changes in capacity utilization have a significant effect on MFP growth in the short-run. For example, over the period 2000 to 2009, MFP without utilization adjustment declined by 0.9 per cent per year over the period. In contrast, MFP adjusted for capacity utilization increased by 0.3 per cent per year.

MFP growth declined in the period 2000 to 2009 compared with the period 1980 to 2000. It fell from 2.1 per cent per year to

13 In general, the utilization of both physical and intangible capital are subject to changes over the short-run. As estimates of intangibles for manufacturing industries are not available, this section will focus on the adjustment of multifactor productivity growth for changes in the utilization of physical capital.

14 The changes in the ex post user cost of capital may also reflect the changes in the prices of output and inputs. Gu and Wang (2013) shows that the changes in the ex post user cost of capital is not correlated with the changes in the price cost markup or the changes in the price of output and inputs in manufacturing and most other industries.

Table 8: **Effects of Changes in Capacity Utilization on Multifactor Productivity Growth in the Manufacturing Sector, 1980-2015 (Average Annual Compound Rate of Change)**

	1980-2000	2000-2015	2000-2009	2009-2015
Unadjusted for Capacity Utilization	2.12	0.31	-0.93	2.18
Adjusted for Capacity Utilization	2.18	0.75	0.32	1.41

Source: Authors calculation based on data from CANSIM Table 383-0021, Statistics Canada.

-0.9 per cent between the two periods, a slowdown of 3.0 percentage points. When changes in capacity utilization are taken into account, the decline is smaller at 1.9 points (from 2.2 per cent per year to 0.3 per cent per year across the two periods). Therefore, the decline in MFP growth between those two periods is partly due to the decline in the utilization of capital in the 2000-2009 period in the manufacturing sector.

During the period after 2009, output and employment showed a positive growth and capacity utilization increased. Multifactor productivity increased 2.2 per cent per year in the 2009 to 2015 period. The positive multifactor productivity growth was largely due to an increase in capacity utilization. Multifactor productivity adjusted for capacity utilization increased by only 1.4 per cent per year.[15]

The Overall Impact of Capital Measurement Issues on MFP Growth after 2000

Table 9 presents the effects on MFP growth in the business sector of incorporating intangible capital, natural capital, public capital, and changes in capacity utilization.[16] MFP growth in the business sector declined by 0.61 percentage points, from 0.43 per cent per year in 1980-2000 to -0.18 per cent in 2000-2015.

When natural capital is included, adjusted MFP growth for the business sector was 0.04 points faster in 1980-2000 and 0.13 points faster in 2000-2015. This means that natural capital boosted MFP growth by 0.09 points between the 1980-2000 and 2000-2015 periods. This reflects an increase in the use of produced capital required to extract natural resources in the oil and gas and mining sector.

When an adjustment is made to MFP for capacity utilization, MFP growth became 0.02 points higher in 1980-2000 and 0.09 points higher in 2000-2015. Like the inclusion of natural capital, this adjustment raises MFP growth between periods, with an increase of 0.07 points. The combined effect of these two factors is to increase MFP growth by 0.16 points between 1980-2000 and 2000-2015. This means that 0.16 points of the 0.61 point decline in MFP growth between 1980-2000 and 2000-2015 or 26 per cent of the MFP slowdown, was due to the exclusion of these two factors from the official MFP calculations.

On the other hand, the exclusion of both public infrastructure capital and the non-SNA components of intangible capital

15 The utilization adjustment based on a comparison of the ex post with the ex ante user cost can be done for the period up to 2011 for which nominal value-added and capital income are available. The capacity utilization in the recent years are extended using the industrial capacity rates from the CAPEX survey.

16 The adjustments to aggregate MFP growth in the business sector from incorporating the effects of capacity utilization and natural capital equal the changes to MFP growth in the manufacturing and mining and oil and gas extraction industries respectively multiplied by their shares of input costs in the total business sector.

Table 9: Multifactor Productivity in the Business Sector With Various Adjustments, 1980-2000 and 2000-2015 (Average Annual Compound Percentage Point Contribution)

	1980-2000	2000-2015	2000-2015 less 1980-2000
Multifactor productivity growth	0.43	-0.18	-0.61
Changes to MFP growth from accounting for the effects of			
Non-SNA intangible capital	0.13	-0.01	-0.14
Public infrastructure capital	-0.08	-0.23	-0.15
Natural capital	0.04	0.13	0.09
Changes in capacity utilization	0.02	0.09	0.07
Adjusted multifactor productivity growth	0.54	-0.20	-0.75

Source: Authors calculation based on data from CANSIM Table 383-0021 and 383-0032, Statistics Canada.

cannot explain slower MFP growth. When public infrastructure capital is included, adjusted MFP growth for the business sector is 0.08 points slower in 1980-2000 and 0.23 points slower in 2000-2015. This means that public infrastructure capital reduced MFP growth by 0.15 points between the 1980-2000 and 2000-2015 periods.

When intangible capital not already in the SNA is included, adjusted MFP growth for the business sector is 0.13 points faster in 1980-2000, but 0.01 points slower in 2000-2015. This means that intangible capital reduced MFP growth by 0.14 points between the 1980-2000 and 2000-2015 periods. The combined impact of these two effects is to decrease MFP growth by 0.29 points between 1980-2000 and 2000-2015. Thus the inclusion of intangible capital and public infrastructure makes the MFP slowdown even larger.

The 0.16 point boost to MFP growth between the 1980-2000 and 2000-2015 periods from natural capital and capacity utilization adjustment is more than offset by the 0.29 point reduction in MFP growth from intangible capital and public infrastructure capital. This means that the net effect of the four factors on MFP growth between the periods is -0.14, as evidenced by the increase in the MFP growth slowdown between 1980-2000 and 2000-2015 from 0.61 points to 0.75 points.

Conclusion

Labour productivity and MFP growth declined in the Canadian business sector after 2000. This article examines the roles of intangible capital, natural capital, public infrastructure capital and capacity utilization in this development. To do that, it first addresses the issues that are associated with their measurement in the national accounts and presents a growth accounting framework that is used to examine their roles in labour and MFP growth.

The article finds that only 25 per cent of the decline in multifactor productivity growth in the Canadian business sector in the period 2000-2015 compared with the period 1980-2000 is due to an increase in the use of produced capital required to extract natural resources with declining ore grade and a decline in the utilization of capital in the manufacturing sector. The decline in labour and MFP growth is not due to changes in intangible capital and infrastructure capital after 2000. Infrastructure capital contributed to an increase in labour and multifactor productivity growth after 2000 as a result of a large increase in infrastructure investment in that period. The overall effect of incorporating intangibles not already included in the SNA is to increase the MFP growth estimate in the period 1980-2000 and reduce the MFP growth estimate in the period 2000-2015 contributing to an even larger decline in MFP growth after 2000.

Labour productivity and MFP growth have slowed in almost all advanced economies (OECD, 2016). This article has focused on the role of measurement issues that are associated with capital input for the slower productivity growth in Canada. The results suggest that the capital measurement issues alone cannot explain the slowdown in productivity in Canada. The future research should focus on the role of other factors in the recent productivity growth slowdown such as innovation, the diffusion of innovation, competition, and on business dynamism.

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