Decomposing Multifactor Productivity Growth in Canada by Industry and Province, 1997-2014

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ABSTRACT

Between 1997 and 2014, multifactor productivity (MFP) in Canada's business sector industries grew at an annual rate of 0.02 per cent per year - essentially zero. In this article, we decompose aggregate MFP growth into contributions by industry and province. Two sets of results are presented: one based on the generalized exactly additive decomposition (GEAD) and one based on the CSLS decomposition. The two decomposition methods lead to very different conclusions. The GEAD suggests that the reallocation of inputs to the mining and oil and gas extraction industry in the oil-rich provinces were the primary drivers of MFP growth in Canada while the manufacturing sector, concentrated in Ontario and Quebec, dragged MFP growth down. The CSLS decomposition suggests precisely the opposite: mining and oil and gas was the main hindrance to Canada's MFP performance while manufacturing was the major driver of MFP growth. The disagreement between the two methods is primarily attributable to the fact that the large increase in commodity prices (especially oil prices) over the 1997-2014 period increases the mining and oil and gas industry's contribution to MFP growth according to the GEAD while the CSLS decomposition does not treat such relative price effects as contributors to productivity growth.

Introduction

Multifactor productivity (MFP) is defined as the quantity of output produced per unit of "aggregate input" used in production.[2] While MFP growth is often treated as synonymous with technological progress, it also reflects other factors such as allocative efficiency, returns to scale, and capacity utilization. An

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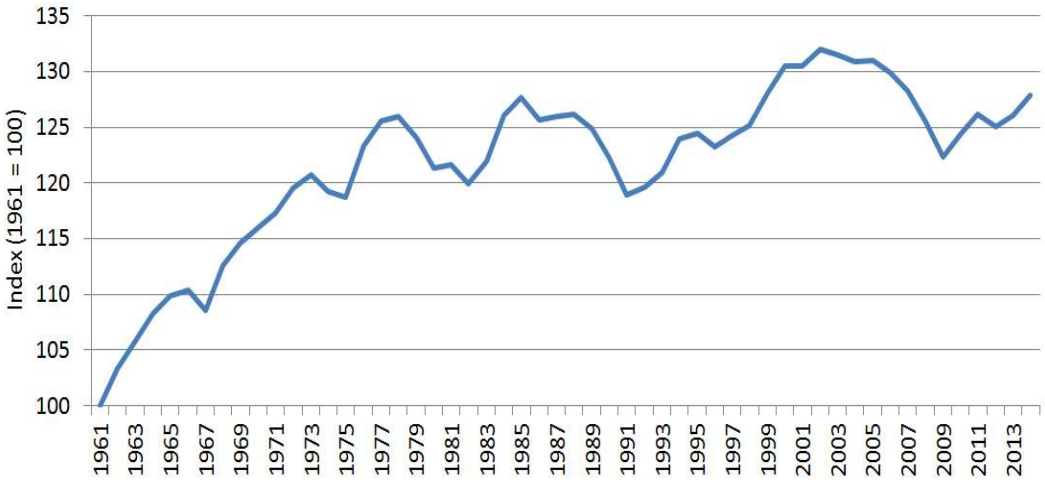
2 MFP is commonly referred to as total factor productivity (TFP). The two terms are synonymous. Since this article is based on Statistics Canada MFP estimates, we use that term.

Chart 1
Multifactor Productivity, Canada, Business Sector, 1961 = 100, 1961-2014



Source: Statistics Canada, CANSIM Table 383-0021

economy with a higher level of MFP is able to produce a higher level of output for a given amount of input, resulting in a higher standard of living for the population. For this reason, policymakers are interested in monitoring trends in MFP and adopting policies which promote MFP growth.[3]

MFP growth in Canada has been disappointing in recent decades. Chart 1 displays Statistics Canada's official index of the level of MFP in the Canadian business sector between 1961 and 2014. Over the entire period, MFP grew at a compound annual rate of 0.5 per cent. There was a clear decline in the trend growth rate in the late 1970s. MFP rose by 26 per cent between 1961 and 1978, but by only 1.5 per cent between 1978 and 2014 (although it had been as high as 4.8 per cent above the 1978 level at its peak in 2002).

The negligible growth of MFP in Canada since the late 1970s has been of major concern to policymakers and is still not well understood. This article shines new light on the modest MFP growth observed in Canada from 1997 to 2014 by quantifying the specific contributions of each province and industry to Canada's overall MFP growth rate. This allows for the identification of sectors that have driven MFP growth in Canada and sectors that have acted as a drag on growth. The existing literature contains similar decompositions using labour productivity growth (Sharpe, 2010; Sharpe and Thomson, 2010; Almon and Tang, 2011; Baldwin and Willox, 2016). However, labour productivity is not as comprehensive a measure of an economy's overall productivity as MFP because labour productivity only considers one input (labour) while MFP is based upon a composite input of labour and capital.[4]

We use two different approaches from the literature in order to decompose aggregate MFP growth into provincial and industry contributions. The first is the generalized exactly additive decomposition (GEAD), developed by

3 See Oulton (2016) and Murray (2016) in this issue of the *International Productivity Monitor* for discussions of the factors that influence MFP.

4 See Murray (2016) for a comprehensive review of the relative strengths and weaknesses of MFP and partial productivity measures.

Tang and Wang (2004) for labour productivity growth and adapted for MFP growth by Diewert (2015). The second is the CSLS decomposition, developed by Sharpe (2009 and 2010) for labour productivity growth and adapted here for use with MFP growth.

There are three key differences between these two approaches. First, the industry contributions in the GEAD are influenced by changes in sectors' relative input and output prices while those in the CSLS decomposition are not. Second, an increase in a sector's share of aggregate inputs always increases that sector's contribution to aggregate MFP growth according to the GEAD, while according to the CSLS decomposition this is only true if the sector in question has an above-average productivity level. Third, the GEAD is exactly additive while the CSLS decomposition is not.[5]

We view the two approaches as complementary rather than competing. Some researchers have criticized the GEAD for the inclusion of relative price effects and for the failure of its reallocation effects to account for the influence of relative productivity levels (de Avillez, 2012; Reinsdorf, 2015). The CSLS decomposition overcomes these criticisms, but at the cost of exact additivity. Which approach is more appropriate depends upon what a researcher is interested in learning. As we will see, the two decomposition formulas lead to radically different conclusions regarding the sources of MFP growth in Canada.

The remainder of the article is organized as follows. In Section II, we provide an overview of the decomposition methods and describe the data. In Section III, we present the results of the MFP growth decomposition exercises, which have not previously been performed using Canadian data. Section IV concludes.

Methodology and Data

We implement two decompositions of MFP growth in this article: the generalized exactly additive decomposition (GEAD) and the CSLS decomposition. In this section, we provide a brief description of each decomposition method. We forego a thorough derivation of the decomposition formulas; those details can be found in Calver and Murray (2016). The section ends with a discussion of the data.

Generalized Exactly Additive Decomposition (GEAD)

The GEAD was developed by Tang and Wang (2004) to address a problem of non-additivity of contributions in the traditional decomposition formula of Denison (1962). The traditional decomposition depends on the additivity of real volume measures; it requires that real aggregate output (or input) be equal to the sum of the real sectoral outputs (or inputs). Additivity always holds in nominal terms, but it does not hold in real terms when chained indexes or Fisher quantity measures are used.[6] To address this problem, Tang and Wang modified the traditional decomposition of labour productivity so that it depends on nominal additivity rather than real additivity. As a result, changes in relative prices of sectoral outputs enter the decomposition formula. The influence

5 In the GEAD, the sectoral contributions sum exactly to the growth of aggregate MFP by construction. In the CSLS decomposition, there is a small discrepancy between aggregate MFP growth and the sum of the sectoral contributions. This is discussed in greater detail below.

6 In the past, non-additivity did not arise because most statistical agencies produced output estimates using constant dollar Laspeyres volume measures. Constant dollar Laspeyres measures have the property that real aggregate output is equal to the sum of real sectoral outputs. Non-additivity became problematic as chained Fisher measures became common.

of relative prices is the core distinction between the GEAD and the traditional approach.

Tang and Wang applied their decomposition to labour productivity growth. Diewert (2015) devised a version of the GEAD for MFP growth, and that is the version we use in this article. Define N sectors over two periods ($t \in \{0,1\}$). For our application, a sector will correspond to an industry-province pair. Let γ denote aggregate MFP growth between time 0 and time 1. The GEAD decomposition formula is:

$$\gamma = \sum_{n=1}^{N} s_{Yn}^{0} \left\{ [1+\gamma_n][1+\rho_n][1+\omega_n][1+\sigma_n] - 1 \right\} \quad (1)$$

Here, s_{Yn}^{0} is the nominal output share of sector n at time 0. The other terms are defined as follows:

Rate of output price growth:

$$\rho_n = (p_n^1 / p_n^0) - 1$$

Rate of (inverse) relative input price growth:

$$\omega_n = (w_n^0 / w_n^1) - 1$$

Rate of within-sector MFP growth:

$$\gamma_n = (X_n^1 / X_n^0) - 1$$

Rate of nominal input cost share growth:

$$\sigma_n = (s_{Zn}^1 / s_{Zn}^0) - 1$$

where p_n^t is the relative price of the output of sector n at time t, w_n^t is the relative price of the bundle of inputs used in sector n at time t, X_n^t is the index of MFP in sector n at time t, and s_{Zn}^t is sector n's share of aggregate nominal input expenditures at time t.

Expanding equation (1) reveals that the contribution of each sector is driven by the growth rates of each of our four factors plus their interaction terms. Generally, the interaction terms will be relatively small. We do not want to assess the fifteen additive terms within each sector in our analysis as this would become quite tedious. Following Diewert (2015), we instead allocate each interaction term equally among its component factors. For example, the contribution of sector n's within-sector MFP growth to aggregate MFP growth can be estimated as:

$$\Delta X_n = s_{Yn}^{0} \gamma_n \left\{ 1 + \frac{(\rho_n + \omega_n + \sigma_n)}{2} + \frac{(\rho_n\omega_n + \rho_n\sigma_n + \omega_n\sigma_n)}{3} + \frac{(\rho_n + \omega_n + \sigma_n)}{4} \right\} \quad (2)$$

Analogous expressions are used for the contributions of output price growth (Δp_n), (inverse) input price growth (Δw_n), and input cost share growth (Δs_{Zn}). Then aggregate MFP growth is given by:

$$\gamma = \sum_{n=1}^{N} \left[\Delta X_n + \Delta p_n + \Delta w_n + \Delta s_{Zn} \right] \quad (3)$$

CSLS Decomposition

A weakness of the GEAD is that the apportionment of the total reallocation effect across sectors is problematic. There are two reasons for this. First, the industry contributions in the GEAD are influenced by changes in sectors' relative input prices and relative output prices even when all sectors' productivities and input shares remain unchanged. This is inconsistent with an interpretation of productivity growth as an outward shift of the production possibilities frontier as a result of technological improvements (Reinsdorf, 2015). Second, an increase in a sector's share of aggregate inputs always increases that sector's contribution to aggregate MFP growth according to the GEAD. That an increase in an industry's share of inputs at the expense of other industries with higher productivity levels is counted as a positive contribution by the industry to aggregate productivity growth is highly counterintuitive.

The CSLS decomposition proposes an alternative definition of sectoral reallocation effects that addresses these weaknesses. In our view, the resulting sectoral contributions to productivity growth are more consistent with economic intuition than the contributions generated by the GEAD. Sharpe (2009), Sharpe (2010) and de Avillez (2012) applied the CSLS decomposition to Canadian labour productivity growth. We adapt the CSLS decomposition for the analysis of MFP growth.

$$\hat{\gamma} = \sum_{n=1}^{N} \left[\hat{s}^{0}_{Yn} \hat{\gamma}_n + \left(\frac{\hat{X}^{0}_{n} - \hat{X}^{0}}{\hat{X}^{0}} \right) \left(\hat{s}^{1}_{Zn} - \hat{s}^{0}_{Zn} \right) + \left(\frac{\left(\hat{X}^{1}_{n} - \hat{X}^{0}_{n} \right) - \left(\hat{X}^{1} - \hat{X}^{0} \right)}{\hat{X}^{0}} \right) \left(\hat{s}^{1}_{Zn} - \hat{s}^{0}_{Zn} \right) \right] \quad (4)$$

Here, $\hat{s}^{0}_{Yn}$ is sector n's share of real output at time 0, $\hat{s}^{t}_{Zn}$ is sector n's share of real inputs at time t, $\hat{\gamma}_n$ is the within-sector MFP growth of sector n, and $\hat{X}^{t}_{n}$ and $\hat{X}^{t}$ are the MFP indexes at date t for sector n and for the aggregate economy, respectively.

The first term on the right-hand side of equation (4) is the contribution to aggregate MFP growth of within-sector MFP growth in sector n. The second term is the reallocation level effect. When an industry's share of real inputs rises, its reallocation level effect is positive if and only if its productivity level is above average. The third term is the reallocation growth effect. When an industry's share of real input rises, its reallocation growth effect is positive if and only if its productivity growth rate is above average. The CSLS decomposition thus embodies the idea that the sign of an industry's reallocation effect should reflect the productivity performance of that industry relative to the other industries from which it is gaining (or to which it is losing) input share.[7]

The fact that the output and input shares ($\hat{s}^{t}_{Yn}$ and $\hat{s}^{t}_{Zn}$) are defined in real terms rather than in nominal terms introduces the problem of non-additivity. Like the traditional decomposition of Denison (1962), the CSLS decomposition depends on the additivity of real volume measures; it requires that real aggregate output (or input) be equal to the sum of the real sectoral outputs (or inputs). Additivity always holds in nominal terms, but it does not hold in real terms when chained indexes or Fisher quantity measures are used. Non-additivity introduces a discrepancy between the sum of the sectoral contributions, $\hat{\gamma}$, and actual aggregate MFP growth, γ. As we will show, the discrepancy turns out to be small.

Data

We implement the GEAD and the CSLS decomposition for "business sector industries" in Canada over the 1997-2014 period.[8] The decompositions yield contributions from each combination of the ten provinces and fifteen two-digit NAICS business sector industries - 150 industry-province pairs in total.

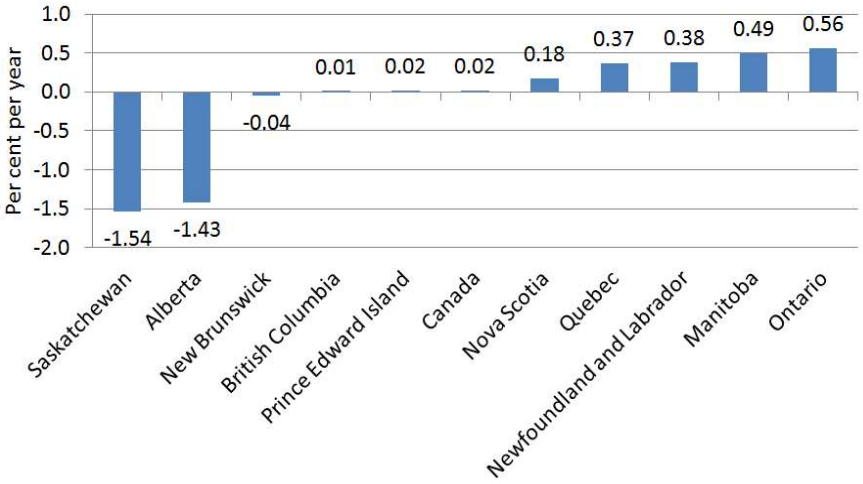
All the data for the decomposition exercises are drawn from Statistics Canada's CANSIM Table 383-0026. We use the annual series on nominal GDP, real GDP, real capital services input, real labour input, nominal labour compensation, and nominal capital costs.[9] Using these data at the industry-province level, we construct aggregates at the provincial level (i.e.

7 One interpretation of the reallocation effects in the CSLS decomposition, due to Reinsdorf and Yuskavage (2010), is that input share 'released' by one industry goes into a common pool from which all other industries can draw. The opportunity cost of inputs in this pool is the average productivity level of the economy. Baldwin and Willox (2016) propose a labour productivity decomposition in which an increase in an industry's labour share is assumed to be drawn from all other industries in proportion to those industries' initial labour shares. It turns out that this decomposition yields a total reallocation effect that is, to a close approximation, a version of the reallocation level effect from the CSLS decomposition. Hence, they provide an alternative motivation for the CSLS decomposition.

8 Business sector industries exclude the public administration, education, and health industries, but the data capture the activities of non-business establishments in the business sector industries. In practice, almost all establishments in our business sector industries are business establishments, so we will sometimes refer to this as 'the business sector.'

9 Nominal GDP is available up to 2012. We extend the series to 2014 using the growth rate of total nominal input costs (i.e. labour compensation plus capital cost). All other series are available to 2014 from CANSIM. The labour input index accounts for the effect of changes in labour quality over time.

Chart 2
Multifactor Productivity Growth in Canada and the Provinces, Business Sector Industries, Per Cent per Year, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.

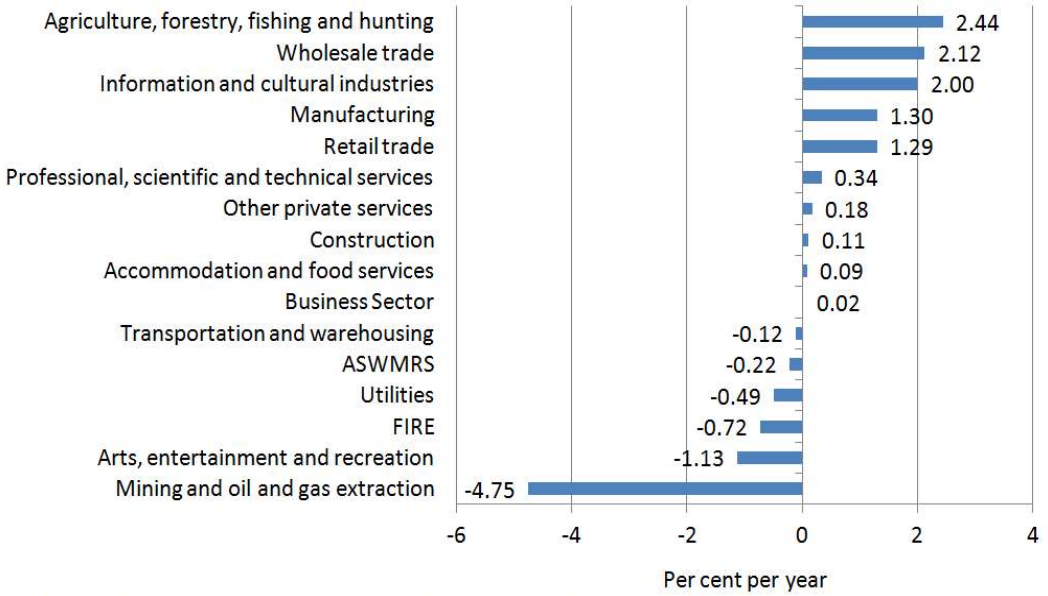
aggregating across all industries), the industry level (i.e. aggregating across all provinces), and the 'national' level (i.e. aggregating across all provinces and industries). Note that these 'national' aggregates do not include the territories. The nominal aggregates are obtained by summing the underlying province-industry sectoral data, while the real aggregates are chained Fisher aggregates as outlined by Landefeld *et al.* (2003). All real quantities are expressed in chained 2007 dollars.

Growth rates of output and aggregate input prices are measured using implicit price deflators. The growth rates of aggregate input prices in each sector are calculated as the growth rates of the implicit input price deflator (with nominal input measured as the sum of labour compensation and capital cost).[10] Similarly, the growth rates of aggregate output prices in each sector are calculated as the growth rates of the implicit output price deflator.

Finally, some conceptual difficulties arise in measuring the relative MFP levels of each sector for the CSLS decomposition. MFP levels for each sector are measured as a unit-free index normalized to 100 in the base year 2007. By construction, all sectors have the same MFP level in the base year. Away from the base year, intersectoral differences in MFP levels arise over time due to differential MFP growth rates in the sectors. We could have constructed an alternative measure of real input by applying the same national prices of capital and labour in constructing aggregate input for each industry-province pair. This would lead to different MFP levels across industries and provinces even in the reference year, with all MFP levels expressed relative to the MFP level of the national aggregate in the reference year. While an approach that generates differing MFP levels in the reference year is desirable, we opt to take the simpler approach here.[11]

10 Note that we do not assume that a sector's total nominal input costs are equal to its total nominal output. Statistics Canada estimates capital costs via a hybrid method that uses both internal and external rates of return. As a result, total nominal input costs are in general not equal to nominal output. The discrepancy may reflect factors such as imperfect competition and non-constant returns to scale. See Baldwin *et al.* (2014) for a discussion. In any event, the decomposition formulas we apply do not depend on the equivalence of nominal output and nominal inputs.

Chart 3
Multifactor Productivity Growth by Business Sector Industry, Canada, Per Cent per Year, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

Results

Overview of MFP Growth by Province and Industry

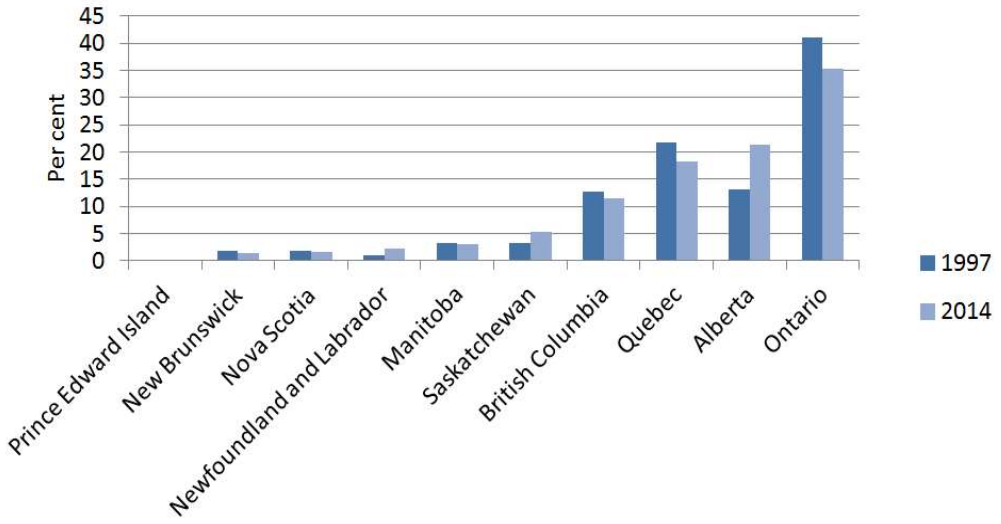
Before presenting the results of our decompositions, it is informative to discuss the underlying trends in each sector (industry-province pair) of the economy. Since the GEAD breaks MFP growth into contributions related to changes in MFP within each sector, the input and output prices of the sector, and the inputs shares of each sector, an understanding of how these factors have changed across industries will provide some insight into what drives the decomposition results.

We begin with aggregate MFP growth. Between 1997 and 2014, our estimates show that cumulative growth in MFP in Canada's business sector industries was 0.28 per cent. This amounts to a growth rate of 0.02 per cent per year - essentially zero (Chart 2). Statistics Canada's official estimates for the aggregate business sector (depicted in Chart 1 at the beginning of this article) put national MFP growth over the 1997-2014 period at 2.9 per cent cumulatively, or 0.16 per cent per year. The 0.14 percentage-point discrepancy between the annual growth rates may reflect differences in geographic coverage (i.e. the exclusion of the territories from our 'national' estimates) and small methodological differences between Statistics Canada's provincial and national MFP databases.[12]

11 We have experimented with generating results using national input prices to obtain differential MFP levels in the reference year. Doing so does not seem to significantly change our conclusions, although the magnitudes of aggregate MFP growth and the contributions associated with each industry change.

12 In particular, the national MFP program includes land and inventories as components of the capital stock and accounts for tax parameters in the estimation of user costs. The provincial capital services data do not account for these factors. See Gu and Lee (2013).

Chart 4
Distribution of Nominal Input Costs Across Provinces, Per Cent, 1997 and 2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.

Over the 1997-2014 period, MFP declined in three provinces: Saskatchewan (-1.54 per cent per year), Alberta (-1.43 per cent per year), and New Brunswick (-0.04 per cent per year). Five provinces exhibited non-negligible positive MFP growth. The fastest growth was in Ontario, at 0.56 per cent per year.[13]

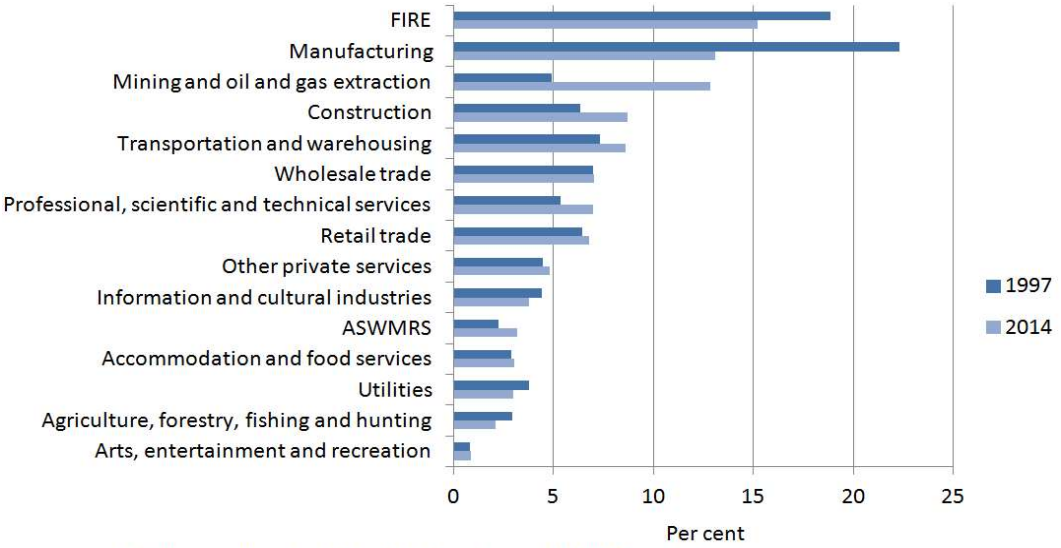
Given that Saskatchewan and Alberta both experienced significant growth in their natural resource sectors over the period, their declining MFP was likely linked to the oil and gas sector tapping into more marginal resources as soaring prices made them financially viable. However, the third major oil producing province, Newfoundland and Labrador, experienced positive MFP growth over the period. This suggests that the effects of the oil and gas boom are more nuanced.[14]

The notion that the oil and gas sector played a significant role in the poor productivity growth observed in Alberta and Saskatchewan is supported by Chart 3, which reveals that the mining and oil and gas extraction industry had by far the worst MFP growth of all business sector industries from 1997 to 2014 (-4.75 per cent per year). Substantial MFP declines also occurred in arts, entertainment and recreation (-1.13 per cent per year); finance, insurance, real estate, and leasing (FIRE) (-0.72 per cent per year); and utilities (-0.49 per cent per year). Three industries exhibited MFP growth of

13 Our provincial estimates of MFP growth are very similar to the official Statistics Canada estimates. Across provinces, the correlation of our compound annual MFP growth estimates for 1997-2014 with the estimates of Statistics Canada is 0.995.

14 Productivity growth in the oil and gas industry in Newfoundland and Labrador is linked to the nature of offshore oil production. Several offshore oil wells began operating in the province in the late 1990s. These offshore wells represented the major capital inputs to the industry in the province, and the capital stock expanded at a much slower pace than that observed in Alberta and Saskatchewan over the 1997-2014 period. MFP growth was strong in mining and oil and gas extraction in the province because capital input growth was limited while output significantly increased, likely due to increased capacity utilization of the new offshore wells. For a detailed discussion of how rising oil and gas prices affected the labour productivity of the three major oil producing provinces directly and indirectly, see Sharpe and Waslander (2014). For an analysis of the overall productivity performance of Newfoundland and Labrador since 1997, see Grand'Maison and Sharpe (2013).

Chart 5
Distribution of Nominal Input Costs Across Business Sector Industries, Per Cent, 1997 and 2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

2.0 per cent per year or more: agriculture, forestry, fishing and hunting (2.44 per cent per year); wholesale trade (2.12 per cent per year); and information and cultural industries (2.00 per cent per year). MFP growth in manufacturing, at 1.30 per cent per year, was also well above the business sector average.

Sectoral contributions to aggregate productivity growth also depend on the sectors' relative sizes. Chart 4 and Chart 5 show the relative sizes of the provinces and industries in terms of nominal input costs in both 1997 and 2014.[15]

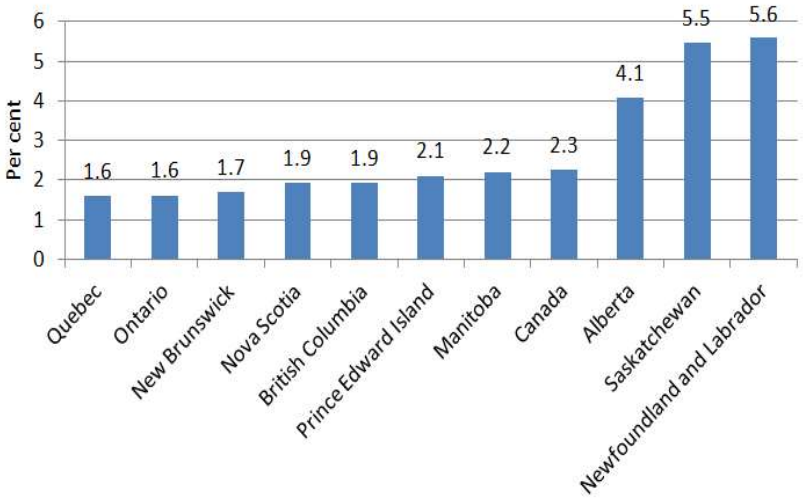
The most notable feature of Chart 4 is that Alberta, Saskatchewan, and Newfoundland and Labrador have experienced significant growth in the sizes of their economies relative to the other provinces, while Ontario, Quebec, and British Columbia have experienced relative declines in size. Ontario's share of nominal input costs in the business sector industries fell from 41.1 per cent in 1997 to 35.4 per cent in 2014 while Alberta's rose from 13.0 per cent to 21.3 per cent.

Several industries experienced large changes in their shares of aggregate input costs between 1997 and 2014. Manufacturing's share of total input costs fell from 22.3 per cent in 1997 to 13.1 per cent in 2014, and FIRE's share fell from 18.9 per cent to 15.2 per cent over the period. Meanwhile, mining and oil and gas extraction's share rose from 4.9 per cent to 12.9 per cent and construction's share rose from 6.3 per cent to 8.7 per cent. Given the geographic concentrations of mining and oil and gas and manufacturing, the developments in these industries are closely related to the provincial trends observed in Chart 4.

Overall, these patterns suggest that economic resources have been reallocated toward the mining and oil and gas extraction industries in Alberta, Saskatchewan, and Newfoundland and Labrador - industries with falling MFP levels.

15 Constructing these charts using nominal GDP rather than nominal input costs would not alter any conclusions about the relative sizes of industries or provinces.

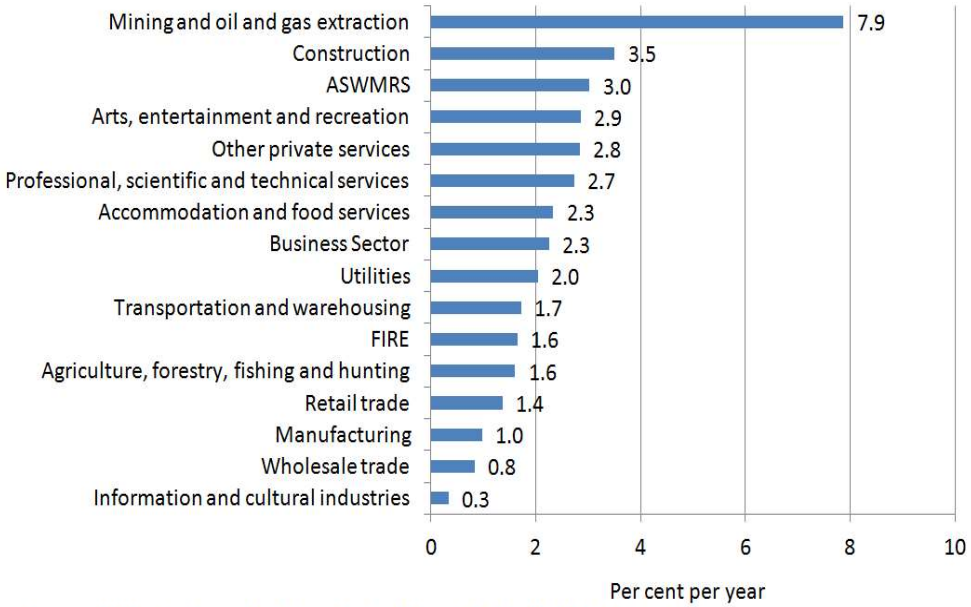
Chart 6
Growth of the GDP Deflator in Canada and the Provinces, Business Sector Industries, Per Cent per Year, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.

Resources have been reallocated away from the manufacturing industry in Ontario and Quebec - an industry with rising MFP. Everything else being equal, this should lead to lower aggregate MFP growth.[16] In the GEAD, the rising relative price of mining and oil and gas sector output and the falling relative price of manufacturing sector

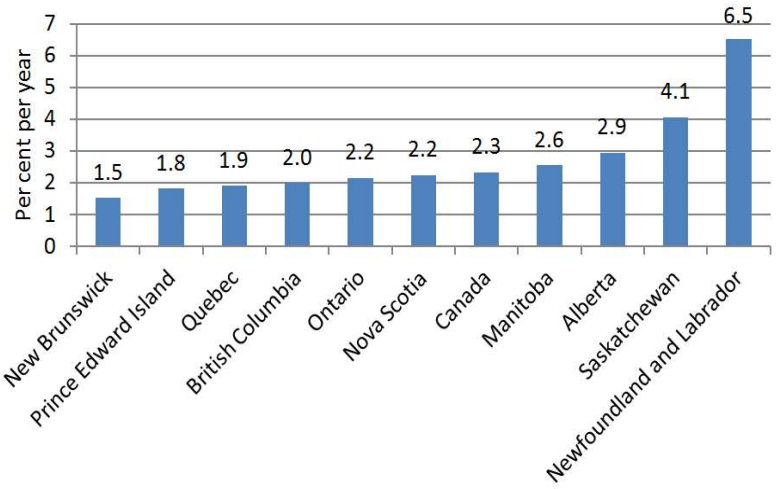
Chart 7
Growth of the GDP Deflator by Business Sector Industry, Canada, Per Cent per Year, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

16 In principle, this reallocation of resources could yield faster aggregate MFP growth through a strong reallocation level effect if the MFP level of mining and oil and gas is very high relative to that of manufacturing.

Chart 8
Growth of the Implicit Input Price Deflator in Canada and the Provinces, Business Sector Industries, Per Cent per Year, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.

output will provide a countervailing force. We now examine these price changes in more detail.

Output and Input Prices

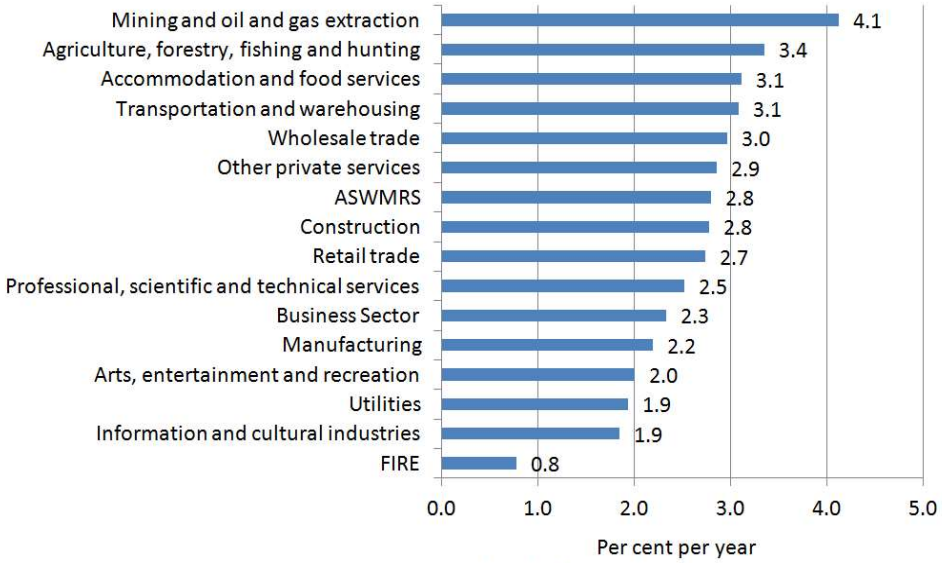
If the output of a sector becomes more valuable relative to that of other sectors over time, reflected in a rising relative price of the output of the sector, then the GEAD ascribes a larger MFP contribution to that sector. The price of the aggregate output of the business sector across all provinces grew by 2.3 per cent per year over the 1997-2014 period (Chart 6). Three provinces experienced significantly above average output price growth: Newfoundland and Labrador (5.6 per cent per year), Saskatchewan (5.5 per cent per year), and Alberta (4.1 per cent per year). This reflects the effects of rising natural resource prices, especially oil prices. Price growth was relatively modest in the other provinces. The lowest rates of output price growth were in Quebec and Ontario, each at 1.6 per cent per year.

At 7.9 per cent per year, output price growth in mining and oil and gas extraction was more than double the next highest output price growth rate among the fifteen business sector industries over the 1997-2014 period (Chart 7). As we shall see, this will translate into large MFP growth contributions from the mining and oil and gas extraction industry under the GEAD but not under the CSLS decomposition. Construction had the second-highest output price growth rate, at 3.5 per cent per year. Output price growth was lowest in information and cultural industries (0.3 per cent per year) and in wholesale trade (0.8 per cent per year).

The GEAD framework also accounts for changes in relative input prices. If a sector's bundle of inputs grows more expensive relative to the bundle of inputs used in the economy as a whole, that sector's contribution to MFP growth declines; the rising real value of inputs (everything else being equal) reduces the value of the sector's output relative to its inputs. Changes in input prices may reflect changes in the quality of the inputs or changes in the opportunity cost of using the input (i.e. firms could substitute a greater quantity of other inputs which have become relatively cheaper).

Chart 8 displays the rates of input price growth by province for the 1997-2014 period. As in the case of output price growth, the three

Chart 9
Growth of the Implicit Input Price Deflator by Business Sector Industry, Canada, Per Cent per Year, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

highest rates of input price growth over the 1997-2014 period were in Newfoundland and Labrador (6.5 per cent per year), Saskatchewan (4.1 per cent per year), and Alberta (2.9 per cent per year). This is not too surprising because rising output growth in a sector raises demand for the inputs of that sector, which in turn raises the prices of those inputs. Thus, to some extent, the effects of changing relative output prices should be expected to be offset by those of changing input prices in the GEAD. The lowest input price growth rates were in New Brunswick (1.5 per cent per year) and Prince Edward Island (1.8 per cent per year).

Given the provincial patterns, it is unsurprising that the fastest input price growth among industries occurred in mining and oil and gas extraction, at 4.1 per cent per year (Chart 9). The slowest input price growth over the 1997-2014 period was in FIRE (0.8 per cent per year).

Decomposition Results: GEAD

Table 1 summarizes the MFP growth decomposition for the 1997-2014 period based on the GEAD. The contributions of each province and industry to overall MFP growth are expressed in percentage points. The total contribution of each industry or province is the sum of four effects primarily associated with four factors: within-sector MFP growth, growth in relative output prices, (inverse) growth in relative input prices, and growth in the sector's share of total input costs.[17]

First, consider the four factors at the aggregate level. Within-sector MFP growth contributed 0.14 percentage points to aggregate MPF growth. This amounts to 50 per cent of Canada's 0.28 per cent cumulative MFP growth over the 1997-2014 period. Each of the other three effects is much larger in absolute value than the within-sector MFP growth effect: relative out-

17 Recall that each of the four components contains an equal share of the factor's interaction effects with the other factors.

Table 1
Contributions by Provinces and Business Sector Industries to Multifactor Productivity Growth in Canada, GEAD, Percentage Points, 1997-2014

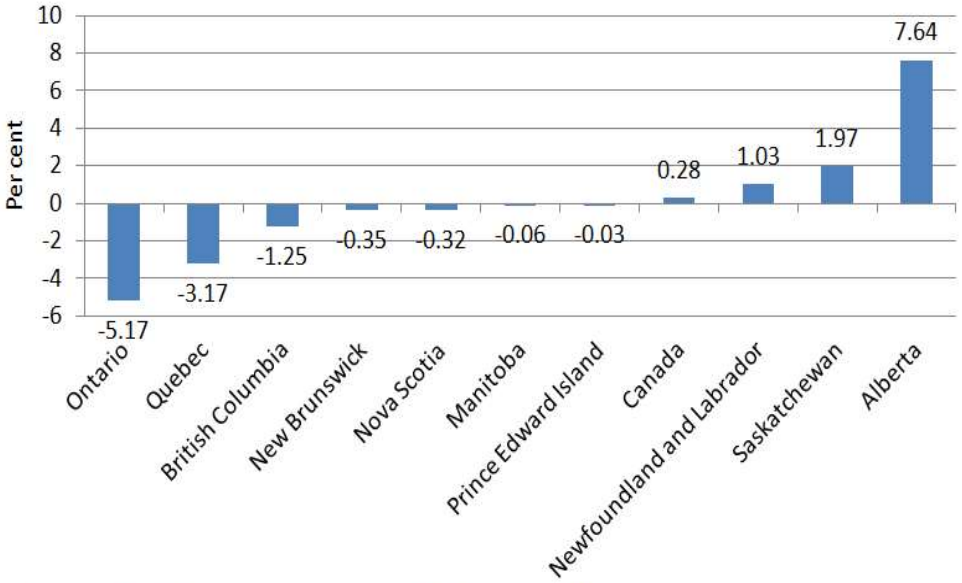
	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Effect
Total	0.14	1.91	-3.15	1.38	0.28
Province					
Alberta	-4.11	5.35	-2.61	9.00	7.64
British Columbia	0.13	-0.66	0.65	-1.37	-1.25
Manitoba	0.24	0.03	-0.20	-0.13	-0.06
New Brunswick	-0.03	-0.13	0.20	-0.39	-0.35
Newfoundland and Labrador	0.75	1.04	-2.26	1.50	1.03
Nova Scotia	0.03	-0.11	0.06	-0.30	-0.32
Ontario	3.89	-4.25	1.15	-5.96	-5.17
Prince Edward Island	0.00	-0.01	0.03	-0.05	-0.03
Quebec	1.19	-2.16	1.41	-3.61	-3.17
Saskatchewan	-1.95	2.80	-1.56	2.69	1.97
Industry					
Accommodation and food services	0.04	0.04	-0.37	0.15	-0.15
ASWMRS	-0.10	0.41	-0.29	1.13	1.15
Agriculture, forestry, fishing and hunting	1.07	-0.26	-0.45	-0.86	-0.51
Arts, entertainment and recreation	-0.17	0.09	0.05	0.04	0.01
Construction	0.17	1.87	-0.86	2.95	4.13
FIRE	-2.23	-1.80	4.66	-3.74	-3.11
Information and cultural industries	1.37	-1.29	0.30	-0.63	-0.24
Manufacturing	3.95	-3.88	0.53	-9.57	-8.96
Mining and oil and gas extraction	-8.11	9.01	-4.28	9.25	5.88
Other private services	0.17	0.50	-0.48	0.42	0.62
Professional, scientific and technical services	0.42	0.49	-0.27	1.71	2.35
Retail trade	1.42	-0.97	-0.44	0.36	0.37
Transportation and warehousing	-0.06	-0.52	-0.72	0.88	-0.41
Utilities	-0.31	-0.11	0.24	-0.79	-0.98
Wholesale trade	2.52	-1.66	-0.77	0.07	0.15

Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

put price growth contributed 1.91 percentage points, (inverse) relative input price growth contributed -3.15 percentage points, and input share growth contributed 1.38 percentage points. As shown by Diewert (2016), however, these three effects are approximately offsetting in the aggregate. In total they contributed just 0.14 percentage points to cumulative MFP growth.

It is important to emphasize that the small combined contribution of the price and reallocation effects to aggregate MFP growth is a mathematical result that should always hold (to a close approximation, at least) while the small

Chart 10
Contributions by Provinces to Multifactor Productivity Growth in Canada, GEAD, Percentage Points, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.

contribution of within-sector MFP growth is an empirical result that could have been different if Canada's productivity performance over the 1997-2014 period had been better.

While the price and reallocation effects are approximately offsetting in the aggregate, they do have a substantial effect on the province and industry contributions. We turn to these contributions now.

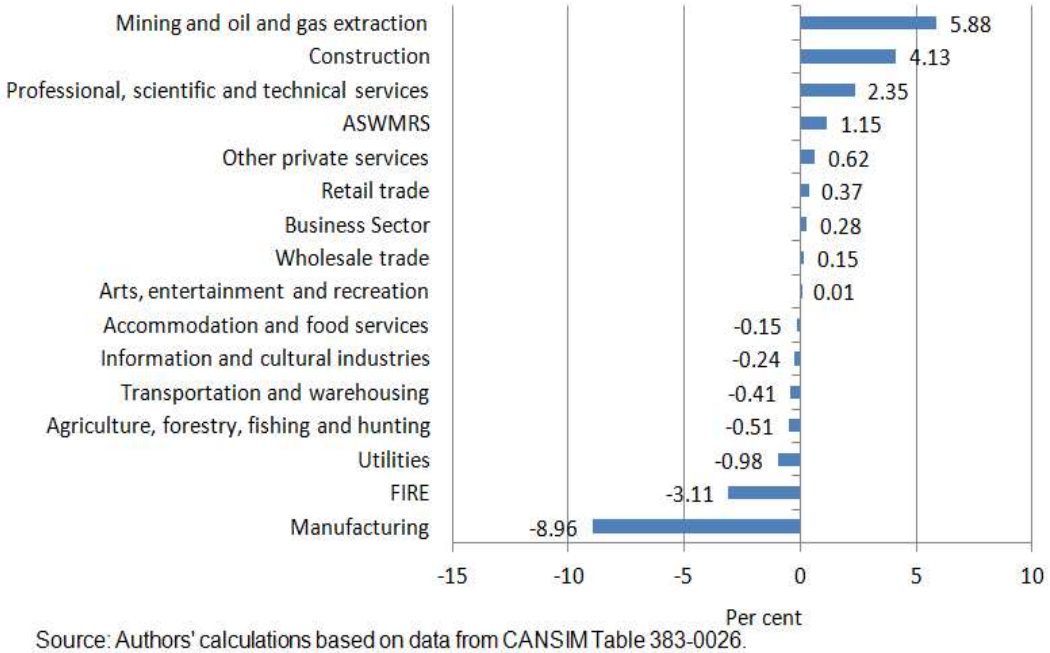
Among the provinces, Alberta made by far the largest contribution to aggregate MFP growth, at 7.6 percentage points (Chart 10). Saskatchewan (at 2.0 percentage points) and Newfoundland and Labrador (at 1.0 percentage points) also made positive contributions. The largest negative contributions were from Ontario (-5.2 percentage points) and Quebec (-3.2 percentage points).

The positive contributions of Alberta and Saskatchewan to overall MFP growth were entirely attributable to large relative output price growth effects and input share growth effects experienced in those two provinces. Both provinces exhibited negative within-sector MFP growth, but the output price and input share effects swamped the direct within-sector MFP growth effects. The same explanation applies in Quebec and Ontario with the signs reversed; both had positive within-sector MFP growth, but large negative output price and input share effects led to negative total contributions.

Given the provincial decomposition, it is not surprising that the mining and oil and gas extraction industry was the largest contributor to aggregate MFP growth (Chart 11). The industry contributed 5.9 percentage points to overall MFP growth over the 1997-2014 period. Negative within-sector MFP growth contributed -8.1 percentage points, while rising relative input prices in the industry made a further contribution of -4.3 percentage points. These negative effects were more than offset by large positive contributions from relative output price growth (9.0 percentage points) and input share growth (9.3 percentage points).

Manufacturing made by far the smallest (i.e. most negative) contribution to overall MFP

Chart 11
Contributions by Business Sector Industries to Multifactor Productivity Growth in Canada, GEAD, Percentage Points, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

growth, at -9.0 percentage points. Again, the total effect differs in sign from the direct within-sector MFP growth effect. Manufacturing's positive MFP growth contributed 4.0 percentage points to overall MFP growth, while relative input price changes contributed a further 0.5 percentage points. However, these effects were more than offset by the negative contributions from relative output price growth (-3.9 percentage points) and input share growth (-9.6 percentage points).

Clearly, the provincial patterns displayed in Chart 10 and the industry patterns in Chart 11 are related. The large increase in commodity prices over the 1997-2014 period resulted in a substantial expansion of economic activity in the mining and oil and gas industry, which is concentrated in Alberta, Saskatchewan and Newfoundland and Labrador. At the same time, the opposite was occurring in the manufacturing sector, which is concentrated in Ontario and Quebec. These price growth and input reallocation effects dominated the effect of within-sector MFP growth, which was positive in manufacturing and negative in mining and oil and gas.

Among the remaining industries, significant positive contributions to overall MFP growth came from construction (4.1 percentage points) and professional, scientific and technical services (2.4 percentage points). The FIRE industry made a significant negative contribution of -3.1 percentage points.

We can compare our main results with those of Diewert (2015), who decomposed MFP growth in Australia over the 1995-2012 period. Diewert finds that the contribution to MFP growth from the mining industry exceeds the average MFP growth in the total economy so that mining is the most important positive contributor to an even greater extent than we estimate in Canada. Similar to our findings, output

Table 2
Ten Largest Positive and Negative Province-Industry Contributions to Multifactor Productivity Growth in Canada, GEAD, Percentage Points, 1997-2014

Province	Industry	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Effect
Ontario	Manufacturing	2.39	-2.47	0.48	-6.09	-5.69
Quebec	Manufacturing	0.69	-1.11	0.49	-2.56	-2.50
Quebec	FIRE	-0.49	-0.69	1.32	-1.29	-1.14
British Columbia	FIRE	-0.75	-0.22	1.02	-0.93	-0.88
Ontario	FIRE	-0.23	-0.61	1.19	-1.01	-0.65
British Columbia	Manufacturing	0.55	-0.45	0.02	-0.75	-0.63
Ontario	Utilities	0.03	-0.25	0.09	-0.47	-0.60
British Columbia	Agriculture, forestry, fishing and hunting	0.21	-0.19	0.03	-0.39	-0.34
Quebec	Utilities	0.15	-0.12	-0.08	-0.26	-0.31
Quebec	Information and cultural industries	0.36	-0.39	0.07	-0.32	-0.28
Alberta	Wholesale trade	0.18	0.02	-0.13	0.36	0.42
Quebec	Professional, scientific and technical services	-0.03	0.10	0.07	0.30	0.44
Quebec	Construction	0.09	0.24	-0.01	0.25	0.57
Alberta	Professional, scientific and technical services	0.26	0.24	-0.26	0.55	0.78
Ontario	Professional, scientific and technical services	0.07	0.06	0.05	0.63	0.80
Ontario	Construction	-0.32	0.67	0.18	0.32	0.85
Newfoundland and Labrador	Mining and oil and gas extraction	0.61	1.01	-2.08	1.36	0.91
Saskatchewan	Mining and oil and gas extraction	-2.40	2.35	-0.73	1.96	1.17
Alberta	Construction	0.32	0.51	-0.74	1.75	1.84
Alberta	Mining and oil and gas extraction	-5.00	4.22	-0.70	4.36	2.88

Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

prices and reallocation for mining are found to have made large positive contributions, while within sector MFP growth had a large negative effect. Rising input prices in mining are also found to have had a negative effect, but it is relatively small compared to that which we estimated in Canada. Diewert also estimate a large negative contribution from manufacturing due to falling output prices and a large negative reallocation effect, offset to a limited degree by falling input prices. This is also in line with our results, although we find that there is a significant positive within-sector contribution from manufacturing in Canada while within-sector MFP growth had almost no effect in Australia.

The major trends are clear, but our decomposition at the industry-province level allows for a more disaggregated analysis of the most important contributions within the most important industries and provinces. Table 2 presents the ten industry-province pairs with the largest positive contributions and the ten with the largest negative contributions to aggregate MFP growth between 1997 and 2014. The two largest negative contributions were made by the manufacturing industries of Ontario and Quebec, at -5.7 percentage points and -2.5 percentage points,

respectively. Manufacturing accounts for three of the ten largest negative contributions, while FIRE accounts for an additional three. In the manufacturing cases, positive within-sector MFP growth was more than offset by negative output price growth effects and input share growth effects. In the FIRE cases, within-sector MFP growth also made negative contributions.

The largest positive contribution was from Alberta's mining and oil and gas extraction industry, at 2.9 percentage points. The mining and oil and gas extraction industry accounted for three of the four largest positive contributions to overall MFP growth over the 1997-2014 period, with construction and professional, scientific and technical services each accounting for three of the top ten. The positive contributions of mining and oil and gas extraction were mainly driven by relative output price growth and input share growth, although the industry did exhibit a positive within-sector MFP growth effect in Newfoundland and Labrador.

Finally, we consider detailed breakdowns of the contributions of Alberta and Ontario, the two provinces with the largest impacts on national MFP growth, and of manufacturing and mining and oil and gas extraction, the two industries with the largest impacts on national growth. This will allow us to obtain a sense of whether contributions were broad-based within these categories or concentrated in a few subsectors.

The positive productivity contribution of Alberta is not entirely attributable to the mining and oil and gas extraction and construction industries. These two industries are responsible for 61.8 per cent of Alberta's total contribution. Every other industry in the province also made a positive contribution to overall MFP growth over the 1997-2014 period. Many of the industries made positive contributions via the within-sector MFP growth effect, although the input share growth effect was typically larger.

In contrast, the negative contribution of Ontario is entirely accounted for by the manufacturing industry. Manufacturing's negative contribution accounted for 110 per cent of Ontario's overall MFP growth contribution. That being said, nine of the fifteen industries in Ontario made negative contributions to Canada's MFP growth while six made positive contributions. The largest positive contributions were from construction and professional, scientific and technical services at -16.4 per cent and -15.4 per cent of Ontario's total contribution, respectively.[18] In both cases, the contributions were driven mainly by relative output price growth and input share growth (although professional, scientific and technical services also made a positive within-sector MFP contribution).

Within the manufacturing industry, we find that the negative contribution is concentrated in Ontario and Quebec, which together account for 91.4 per cent of the total contribution of the industry. The manufacturing industries in Saskatchewan and Alberta made positive contributions to overall MFP growth over the 1997-2014 period; they accounted for -1.3 per cent and -0.5 per cent of the industry's total contribution, respectively. In every other province, manufacturing's contribution was negative. The within-sector MFP growth effect made a positive contribution to aggregate MFP growth in every province but New Brunswick, but in most provinces this was swamped by the output price growth and input share growth effects.

The positive contribution of the mining and oil and gas extraction industry is concentrated in Alberta, Saskatchewan and Newfoundland and

18 Remember, Ontario's total contribution was negative. Thus, having accounted for -16.4 per cent of Ontario's total contribution means that the construction industry in Ontario made a positive contribution.

Table 3
Contributions by Provinces and Business Sector Industries to Multifactor Productivity Growth, CSLS Decomposition, Percentage Points, 1997-2014

	Within-Sector MFP Growth	Reallocation Level Effect	Reallocation Growth Effect	Total Effect
Total	2.19	8.05	-11.32	-1.09
Province				
Alberta	-4.01	5.13	-5.76	-4.64
British Columbia	0.34	0.60	-1.00	-0.05
Manitoba	0.27	0.07	-0.15	0.19
New Brunswick	-0.01	0.04	-0.05	-0.02
Newfoundland and Labrador	0.43	-0.30	0.03	0.16
Nova Scotia	0.09	0.05	-0.08	0.06
Ontario	4.33	0.97	-1.99	3.31
Prince Edward Island	0.01	0.01	-0.01	0.01
Quebec	1.45	0.38	-0.62	1.21
Saskatchewan	-0.71	1.10	-1.70	-1.31
Industry				
Accommodation and food services	0.04	0.00	-0.01	0.04
ASWMRS	-0.08	-0.01	-0.03	-0.13
Agriculture, forestry, fishing and hunting	1.16	0.33	-0.50	0.98
Arts, entertainment and recreation	-0.15	0.04	-0.04	-0.16
Construction	0.13	-0.21	0.11	0.02
FIRE	-2.00	0.14	-0.11	-1.97
Information and cultural industries	1.26	0.07	-0.16	1.17
Manufacturing	4.61	1.04	-1.95	3.69
Mining and oil and gas extraction	-7.09	6.17	-7.92	-8.84
Other private services	0.16	-0.01	0.01	0.16
Professional, scientific and technical services	0.36	-0.04	0.07	0.39
Retail trade	1.39	0.00	0.00	1.39
Transportation and warehousing	0.00	0.05	-0.14	-0.09
Utilities	-0.13	0.23	-0.27	-0.17
Wholesale trade	2.54	0.25	-0.36	2.43

Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

Labrador, which together account for 84.4 per cent of the industry's total effect. The industry's contribution was positive in every province except for Nova Scotia. The within-sector MFP growth effect was negative in every province except for Nova Scotia and Newfoundland and Labrador; the positive total contributions from mining and oil and gas extraction in most provinces were driven by the output price growth effect and the input share growth effect.

Decomposition Results: CSLS Decomposition

Table 3 summarizes the MFP growth decomposition for the 1997-2014 period based on the CSLS decomposition. The contributions of each province and industry to overall MFP growth are expressed in percentage points. The total contribution of each industry or province is the sum of three effects: within-sector MFP growth, the reallocation of inputs into sectors with above-average MFP levels, and the reallocation of inputs into sectors with above-average MFP growth rates.

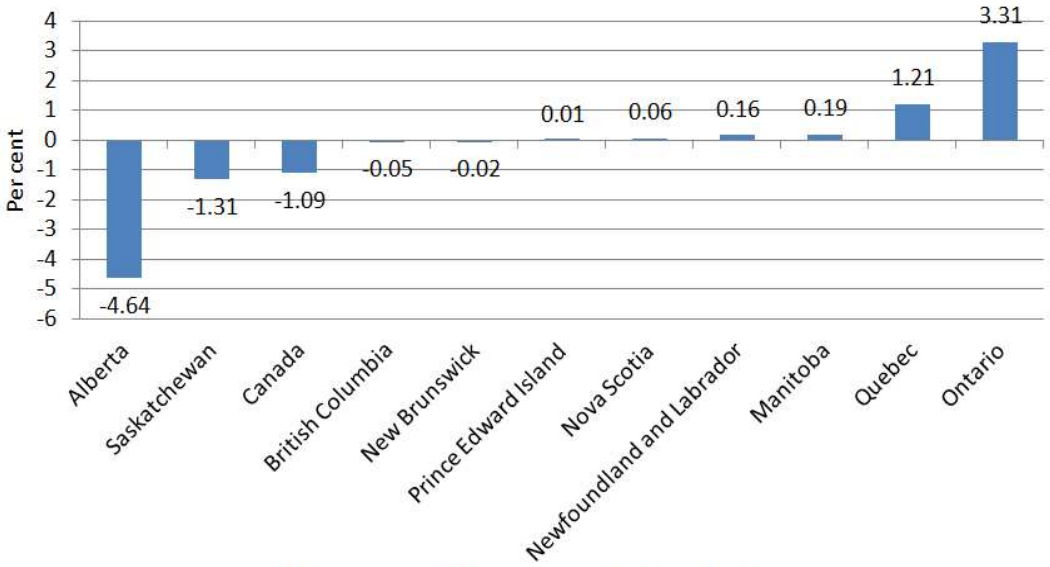
The CSLS decomposition differs from the GEAD decomposition in two important ways. First, the CSLS decomposition does not include changes in relative output or input prices when assessing a sector's contribution to productivity growth. If one is concerned about the value of output generated per (price-adjusted) unit of aggregate input, then the GEAD may be the preferred approach. But, from a traditional perspective of productivity growth representing an outward shift of the production possibilities frontier, it may be preferable to exclude changes in relative prices when assessing the sources of MFP growth by industry and province. Second, the CSLS decomposition only counts reallocation of resources toward a sector as a positive contribution to productivity growth from the sector if the sector has an above average productivity level. We argue that this is more sensible than counting input growth in a sector as a positive contribution from that sector regardless of its productivity level. These two differences lead to extremely different conclusions regarding which provinces and industries generated productivity growth in Canada.

First, we consider MFP growth at the aggregate level.[19] Within-sector MFP growth contributed 2.2 percentage points to overall MFP growth. An additional contribution of 8.1 percentage points arose from the reallocation level effect. This reflects the movement of resources into Canada's mining and oil and gas industry, which has a high productivity level. These positive effects were offset by a negative reallocation growth effect; the movement of resources out of manufacturing (with high MFP growth) and into mining and oil and gas (with negative MFP growth) put downward pressure on overall MFP growth via this channel.

The results based on the GEAD suggested that the mining and oil and gas extraction industry in Alberta, Saskatchewan and Newfoundland and Labrador was the key driver of Canada's MFP growth while the manufacturing industry in Ontario and Quebec was the largest drag on overall MFP growth. The CSLS decomposition suggests precisely the opposite. Under the CSLS decomposition, the two provinces with the largest negative contributions to MFP growth are Alberta and Saskatchewan, at -4.6 percentage points and -1.3 percentage points, respectively (Chart 12). The provinces with the largest positive contributions are Ontario (3.3 percentage points) and Quebec (1.2 percentage points). The provincial patterns reflect the industry patterns. The industry with the largest positive contribution to overall MFP growth is

19 Note that the economy-wide total MFP effect in Table 3 is -1.09 per cent between 1997 and 2014. This differs from the cumulative aggregate MFP growth of 0.28 per cent displayed in Table 1 and in Chart 2. This discrepancy arises from the fact that the CSLS decomposition does not satisfy exact additivity; see the discussion in Section II. Relative to the GEAD, the CSLS decomposition sacrifices exact additivity in exchange for the elimination of price effects and a different (and in our view more sensible) apportionment of the aggregate effect of resource reallocation across industries. The error that arises from non-additivity turns out to be very small. Cumulative changes of 0.28 per cent and -1.09 per cent between 1997 and 2014 amount to annual growth rates of 0.016 and -0.064 per cent per year, respectively. Thus, the annual growth discrepancy is 0.081 percentage points; non-additivity introduces an error of less than one tenth of a percentage point per year.

Chart 12
Contributions by Provinces to Multifactor Productivity Growth, CSLS Decomposition, Percentage Points, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.

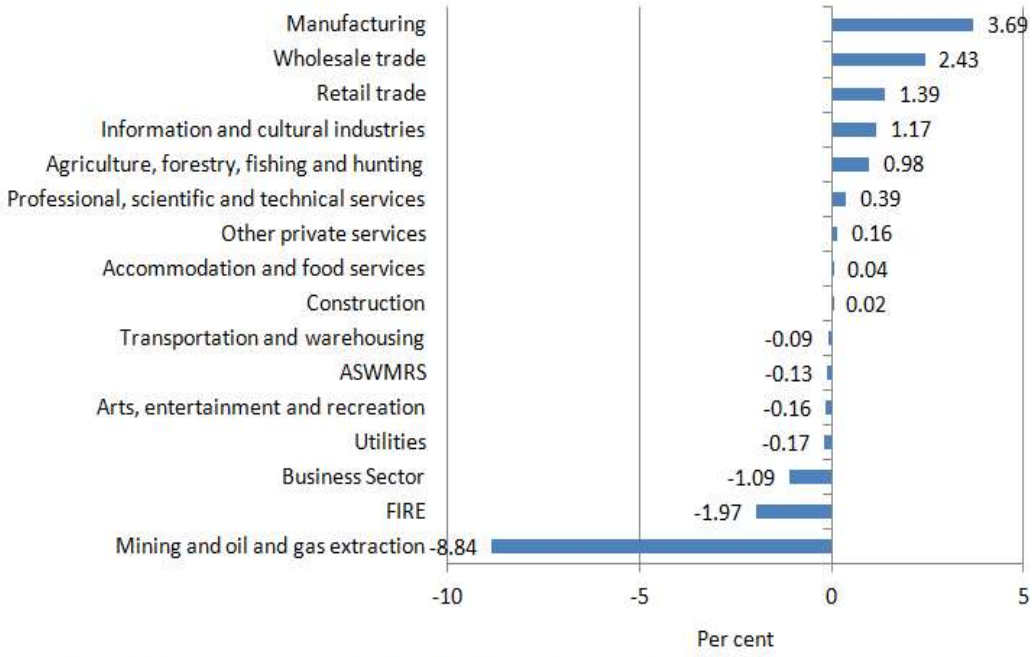
manufacturing, at 3.7 percentage points, while the industry with the largest negative contribution by far is mining and oil and gas extraction at -8.8 percentage points (Chart 13).

As Table 3 indicates, these contributions are mainly driven by within-sector MFP growth. In both manufacturing and mining and oil and gas extraction, and in all the provinces in which those industries are concentrated (Ontario, Quebec, Alberta, and Saskatchewan), the two reallocation effects are more or less offsetting. This leaves the within-sector effect to drive the total contributions. The within-sector MFP growth contribution was -4.0 percentage points in Alberta and -0.7 percentage points in Saskatchewan; both reflect the -7.1 percentage-point contribution of the mining and oil and gas industry. On the other hand, the within-sector MFP growth contribution was 4.3 percentage points in Ontario and 1.5 percentage points in Quebec, with both reflecting the 4.6 percentage-point within-sector effect of the manufacturing industry.

The within-sector effects generated by the CSLS and GEAD decompositions are relatively similar in absolute terms. The large differences in the total contributions assigned to each sector by the two decomposition formulas arise from two sources. First, changes in prices have a large effect if included; they are in the GEAD but not in the CSLS decomposition. Second, the CSLS decomposition's approach to reallocation effects only considers reallocation to make a positive contribution to the extent that a sector's productivity level is above average. This significantly reduces the effects associated with the large reallocation of employment out of manufacturing (Ontario) and into mining and oil and gas extraction (Alberta).

While mining and oil and gas extraction made by far the largest negative contribution among the industries, FIRE also made a significant negative contribution of -2.0 percentage points (Chart 13). This was driven entirely by a -2.0 percentage-point within-sector MFP growth effect. The total contribution of FIRE was negative according to both the GEAD and the

Chart 13
Contributions by Business Sector Industries to Multifactor Productivity Growth, CSLS Decomposition, Percentage Points, 1997-2014



Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

CSLS decomposition; the two decompositions do not disagree about FIRE as they do in the cases of manufacturing and mining and oil and gas extraction.

Table 4 displays the province-industry pairs with the ten largest negative and ten largest positive contributions to overall MFP growth over the 1997-2014 period according to the CSLS decomposition. In terms of the largest negative contributions, the mining and oil and gas extraction industry accounts for four of the top five and five of the top ten. The negative contribution of Alberta's mining and oil and gas extraction sector, at -5.4 percentage points, is by far the largest negative contribution among the 150 province-industry pairs. It was driven by the sector's substantial negative within-sector MFP growth effect, with the two reallocation effects largely offsetting one another. Aside from mining and oil and gas, the FIRE industry accounts for three of the ten largest negative contributions.

Ontario manufacturing made the largest positive contribution to overall MFP growth over the 1997-2014 period, at 2.1 percentage points. It was followed by Ontario wholesale trade at 1.4 percentage points. Positive contributions are less concentrated in specific industries than the negative contributions. Manufacturing and retail trade each accounts for three of the top ten largest positive contributions, while wholesale trade and information and cultural industries each accounts for two. In every case, the positive total contributions were driven by within-sector MFP growth.

Alberta's substantial negative contribution to Canada's MFP growth over the 1997-2014 period was entirely attributable to the mining and oil and gas industry.[20] The next largest contribution in the province was from FIRE, which

Table 4
Ten Largest Positive and Negative Province-Industry Contributions to Multifactor Productivity Growth, CSLS Decomposition, Percentage Points, 1997-2014

Province	Industry	Within-Sector MFP Growth	Reallocation Level Effect	Reallocation Growth Effect	Total Effect
Alberta	Mining and oil and gas extraction	-4.88	5.11	-5.61	-5.38
Saskatchewan	Mining and oil and gas extraction	-1.16	1.05	-1.61	-1.72
British Columbia	FIRE	-0.71	0.01	-0.01	-0.71
British Columbia	Mining and oil and gas extraction	-0.38	0.21	-0.48	-0.65
Ontario	Mining and oil and gas extraction	-0.54	0.08	-0.17	-0.62
Quebec	FIRE	-0.45	0.00	0.00	-0.45
Alberta	FIRE	-0.37	0.12	-0.10	-0.35
Ontario	Construction	-0.27	-0.04	-0.04	-0.35
Alberta	Utilities	-0.21	0.13	-0.19	-0.26
Quebec	Mining and oil and gas extraction	-0.20	0.03	-0.08	-0.24
Quebec	Retail trade	0.24	0.01	-0.01	0.24
British Columbia	Wholesale trade	0.25	0.03	-0.04	0.24
Quebec	Information and cultural industries	0.35	0.05	-0.10	0.30
Alberta	Retail trade	0.31	-0.03	0.04	0.32
Ontario	Retail trade	0.43	0.01	-0.01	0.42
Ontario	Information and cultural industries	0.49	0.00	0.01	0.50
British Columbia	Manufacturing	0.61	0.20	-0.24	0.57
Quebec	Manufacturing	0.78	0.22	-0.27	0.72
Ontario	Wholesale trade	1.50	0.14	-0.24	1.40
Ontario	Manufacturing	2.88	0.63	-1.37	2.13

Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

accounted for just 7.5 per cent of Alberta's total contribution. Ten of the fifteen industries in Alberta made positive contributions to aggregate MFP growth over the 1997-2014 period, but these contributions were swamped by the mining and oil and gas sector.

In contrast, Ontario's positive contribution to overall MFP growth was not concentrated in one industry alone. Manufacturing accounted for 64.5 per cent of Ontario's total contribution, but five other industries made contributions (either positive or negative) that amounted to at least ten per cent of Ontario's total in absolute value. In particular, Ontario's wholesale trade industry contributed 42.5 per cent of the provincial total. In every case, the within-sector productivity growth effect was the largest component of the sector's total effect.

The manufacturing industries in every province except New Brunswick made positive con-

20 See Calver and Murray (2016) for a more detailed discussion of industry contributions for Alberta and Ontario and contributions by province for mining, oil and gas, manufacturing, and FIRE.

tributions to Canada's MFP growth over the 1997-2014 period. Quebec and Ontario together accounted for 77.4 per cent of the industry's total contribution, and British Columbia accounted for another 15.4 per cent. The contributions from manufacturing in all the other provinces were small. In Ontario, Quebec and British Columbia, resource reallocation made a small negative contribution on balance as the reallocation level and growth effects largely offset each other. Within-sector MFP growth was the key driver of the industry's contributions in each province.

The negative contribution of the mining and oil and gas industry to Canada's MFP growth over the 1997-2014 period was concentrated in Alberta and Saskatchewan; those two provinces accounted for 80.3 per cent of the industry's total contribution. The industry made a negative contribution in every province except Nova Scotia and Newfoundland and Labrador. The latter is especially notable. Unlike Alberta and Saskatchewan, Newfoundland and Labrador exhibited positive MFP growth in its mining and oil and gas extraction industry over the 1997-2014 period.

The contribution of FIRE was negative in every province except Saskatchewan, where it was close to zero. The reallocation effects were quite small in most provinces; the exception is Alberta, but even there the two reallocation effects largely offset one another. The total MFP growth contributions were driven by within-sector MFP growth. British Columbia accounted for 36.2 per cent of the aggregate contribution. That province together with Quebec, Alberta and Ontario accounted for 87.1 per cent of the industry's contribution.

Conclusion

Between 1997 and 2014, multifactor productivity (MFP) in Canada's business sector industries grew by 0.28 per cent cumulatively, or 0.02 per cent per year - essentially zero. In this article, we performed two decomposition exercises to identify how different sectors of the economy contributed to this overall performance. The results consistently indicate that Alberta (the mining and oil and gas extraction industry) and Ontario (the manufacturing industry) were the major contributors to aggregate MFP growth over the 1997-2014 period. However, the two decomposition formulas we employ disagree about which of these sectors generated productivity growth and which hindered it.

The generalized exactly additive decomposition (GEAD) includes the effects of changes in relative prices of inputs and outputs. It also assigns compositional effects from resource reallocation in such a way that reallocation of resources to a sector is considered to result in a positive contribution to productivity growth from the sector even if the sector has a below average productivity level. The GEAD finds that Alberta and the mining and oil and gas extraction industry were the major sources of MFP growth in Canada due to rising natural resource prices and reallocation of inputs to these sectors. The manufacturing sector experienced falling output prices and contracted significantly so that it reduced aggregate MFP growth. This negative effect from manufacturing was most highly concentrated in Ontario.

In contrast, the CSLS decomposition excludes price effects and assigns a positive contribution to an industry with a rising input share only to the extent that the industry's productivity level exceeds the average. The CSLS decomposition has previously only been applied to labour productivity; a methodological innovation of this article is the adaptation of the CSLS decomposition to MFP growth. The CSLS decomposition suggests that manufacturing was the largest contributor to the growth of MFP in Canada due to strong within-sector MFP growth. Fifty-eight per cent of manufacturing's contribution

occurred in Ontario. On the other hand, Saskatchewan and Alberta are found to have lowered aggregate MFP growth because of very large declines in MFP within the mining and oil and gas extraction industry.

From a policymaker's point of view, the very different conclusions from the two decomposition methodologies may seem inconvenient. However, the results of both exercises can potentially be useful depending upon what one is interested in. Traditionally, productivity researchers have emphasized the importance of technological progress, which can be viewed as an outward expansion of the production possibilities frontier. Changes in prices should be ignored when attempting to assess productivity from the standpoint of technological change. The CSLS decomposition may be better suited for assessing how provinces and industries are contributing to "real" productivity growth nationally. However, the ultimate goal of public policy is not to maximize physical productivity growth, but the total value of production. From this point of view, incorporating price changes may be more relevant for understanding how changes in the value of output per unit of input have contributed to rising living standards. The GEAD is better suited for this purpose. However, the CSLS decomposition can provide valuable insights to policymakers seeking to identify opportunities to improve "real" productivity, which is an important factor in determining aggregate living standards.

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