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CENTRE FOR THE STUDY OF LIVING STANDARDS

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 report, 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.

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Executive Summary

Multifactor productivity (MFP) is defined as the quantity of output produced per unit of "aggregate input" used in production. While MFP growth reflects many factors in the short term − capacity utilization, non-constant returns to scale and imperfect competition, among others − in the long term it mainly reflects technological progress and is a key driver of changes in living standards.

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 report, we shine new light on this poor MFP growth performance by decomposing Canada's overall MFP growth into the specific contributions of each province and industry. This allows for the identification of sectors that have driven MFP growth in Canada and sectors that have acted as a drag on growth.

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 formulas are derived in Section II of the report, and the relative strengths and weaknesses of each are discussed. Section III presents the results. 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.

Decomposition Methods

We present results based on two decomposition methods: the generalized exactly additive decomposition (GEAD) and one based on the CSLS decomposition.

Let the aggregate business sector be divided into N sectors. (In this report, a 'sector' corresponds to an industry-province pair.) The GEAD decomposes aggregate MFP growth into N industry contributions, each of which is the sum of four components:

$$Aggregate\ MFP\ Growth = \sum_{n=1}^{N} [\Delta X_n + \Delta p_n + \Delta w_n + \Delta s_{Zn}]$$

where

ΔX_n = within-sector MFP growth of sector n

Δp_n = growth of the relative price of sector n's output

Δw_n = inverse growth of the relative price of sector n's inputs

Δs_{Zn} = growth of sector n's nominal share of aggregate inputs

Thus, a sector's contribution to aggregate MFP growth rises when a) that sector's own MFP growth rate rises; b) that sector's relative output price rises; c) that sector's relative input price falls; or d) that sector's share of aggregate input expenditures rises.

The CSLS decomposition decomposes aggregate MFP growth into N industry contributions, each of which is the sum of three components:

$$Aggregate\ MFP\ Growth = \sum_{n=1}^{N} [WSE_n + RLE_n + RGE_n]$$

where

WSE_n = within-sector MFP growth of sector n

RLE_n = reallocation level effect of sector n

RGE_n = reallocation growth effect of sector n

The first term is the contribution to aggregate MFP growth of within-sector MFP growth in sector n and is essentially the same as ΔX_n in the GEAD. The second and third terms capture the effect of input reallocation across sectors on aggregate MFP growth. 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. 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.

There are two 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. We view the two approaches as complementary rather than competing; which approach is more appropriate depends upon what a researcher is interested in learning.

Results

We implement the GEAD and the CSLS decomposition for the 1997-2014 period using Statistics Canada data on real and nominal output, capital input and labour input for the Canadian provinces and business sector industries. Key results include the following:

MFP growth by province and industry

- 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.

- 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.

- 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). The fastest MFP growth was in 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.

Decomposition results: GEAD

- According to the GEAD, within-sector MFP growth contributed 0.14 percentage points to aggregate MPF 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 output 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.

- Among the provinces, Alberta made by far the largest contribution to aggregate MFP growth, at 7.6 percentage points. 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).

- Among industries, mining and oil and gas extraction made the largest contribution to aggregate MFP growth, at 5.9 percentage points. That industry's negative within-sector MFP growth effect, -8.1 percentage points, was more than offset by large positive relative price and input share effects.

- Manufacturing made by far the smallest (i.e. most negative) contribution to overall MFP 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, but this was more than offset by negative contributions from relative output price growth and input share growth.

Decomposition results: CSLS decomposition

- According to the CSLS decomposition, 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.

- 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. The provinces with the largest positive contributions are Ontario (3.3 percentage points) and Quebec (1.2 percentage points).

- The industry with the largest positive contribution to overall MFP growth is 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.

Discussion of the results

The CSLS and GEAD decompositions generally agree about the directions of the major within-sector effects. 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 included 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).

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.

On the other hand, the ultimate goal of economic policy is not to increase physical productivity but rather to raise living standards; that is, the total *value* of production per hour or per person. 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. That being said, the CSLS decomposition can provide valuable insights to policymakers seeking to identify opportunities to improve "real" productivity, which is an important driver of growth in aggregate living standards over the long term.

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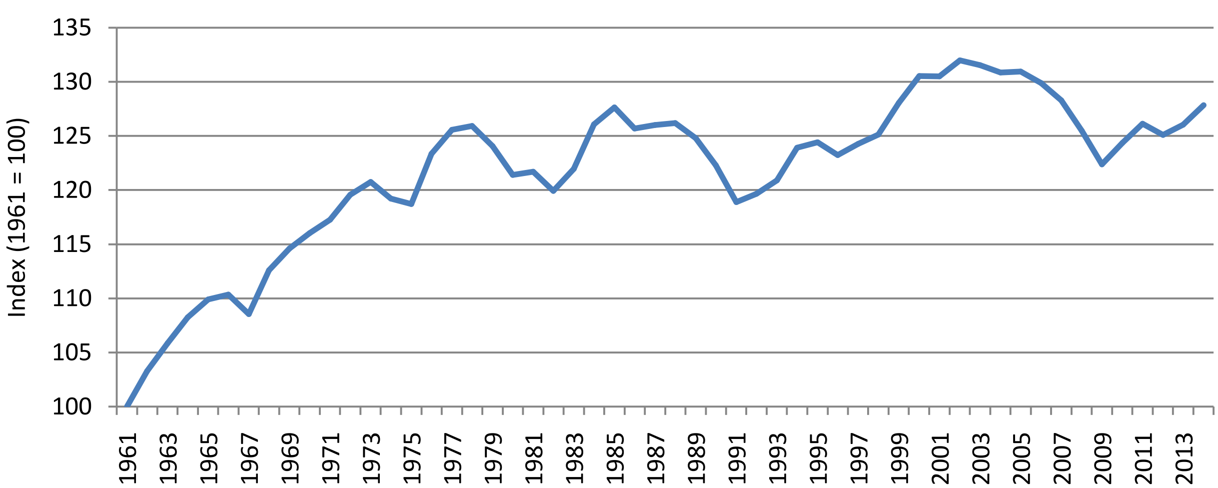
I. Introduction

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.[3] An 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.

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).

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



Source: Statistics Canada, CANSIM Table 383-0021

[1] Matthew Calver is an economist at Finance Canada and Alexander Murray is an economist at the Centre for the Study of Living Standards (CSLS). This report was written when Calver was an economist at the CSLS. An earlier version was presented at the Michael Denny Memorial Session at the annual meeting of the Canadian Economics Association, University of Ottawa, June 3-5, 2016. The authors thank discussant Shutao Cao for comments and session organizer Erwin Diewert for the invitation to resent the paper and for comments.
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[2] MFP is commonly referred to as total factor productivity (TFP). The two terms are synonymous.

[3] See Oulton (2016) and Murray (2016) for discussions of the factors that influence MFP.

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 report will shine 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). Tang and Wang (2004) developed the GEAD for labour productivity growth, and Diewert (2015) adapted it for MFP growth. The GEAD has been criticized by some researchers because it includes changes in relative prices and can assign counterintuitive contributions to productivity growth to industries that experience large relative price shocks (de Avillez, 2012; Reinsdorf, 2015).[5] For this reason, we perform a second decomposition using the "CSLS decomposition" of Sharpe (2009; 2010), adapted for use with MFP growth. The CSLS decomposition overcomes the criticisms the GEAD has faced, but at the cost of exact additivity.[6] We view these two approaches as complementary rather than competing, as a researcher may or may not wish to include price effects in the decomposition depending upon what they are interested in learning. As we will see, the two decomposition formulae lead to radically different conclusions regarding the sources of MFP growth in Canada.

The remainder of the report 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. Novel extensions of both the GEAD and CSLS decompositions that allow for the decomposition of aggregate MFP growth into contributions related to each factor of production (capital and labour) and a new alternative approach to the assignment of reallocation are provided in the appendix.

II. Methodology and Data

In this section, we first present the generalized exactly additive decomposition (GEAD) of MFP growth as formulated by Diewert (2015). We relate it to the "traditional" decomposition of Denison (1962). We then present a third decomposition, the CSLS decomposition, and argue

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

[5] Another issue is that, assuming prices remain constant, a reallocation of resources towards a sector with the lowest productivity level in the economy (and, hence, away from industries with higher productivity levels) is interpreted as a positive contribution to aggregate productivity growth by that sector.

[6] 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.

that its assignment of reallocation effects across sectors is more sensible than those of the GEAD and the traditional decomposition. The section closes with a discussion of the data.

A. 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.[7] 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 of relative prices is the core distinction between the GEAD and the traditional approach.

The traditional decomposition may be regarded as a special case of the GEAD in which the effects of relative price changes are ignored. In this sense, the GEAD can be thought of as the more general approach. For this reason, we begin with a description of the GEAD.

Our presentation follows that of Diewert (2015).[8] Define N sectors over two periods ($t \in \{0,1\}$). For our application, a sector will correspond to an industry-province pair. Real output in sector n at time t is denoted Y_n^t with a corresponding price index P_n^t.

Economy-wide real output in period t, Y^t, will be defined in terms of total nominal value added in all sectors divided by an aggregate price index P^t. So

$$Y^t = \sum_{n=1}^{N} \frac{P_n^t Y_n^t}{P^t} = \sum_{n=1}^{N} p_n^t Y_n^t$$

where $p_n^t = \frac{P_n^t}{P^t}$ is the relative price of the output of sector n.

Each sector uses M inputs. These M inputs are aggregated to obtain an aggregate input index for the sector, Z_n^t, with a corresponding aggregate input price W_n^t.

We also define economy-wide aggregate input. Just like above, we can express aggregate total economy input in terms of input within each sector:

[7] 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.

[8] We present the version of the GEAD developed by Diewert (2015) rather than that of Tang and Wang (2004) for two reasons. The first is that Diewert's multiplicative decomposition of the MFP growth factor provides a “cleaner” separation of the price and reallocation effects than that of Tang and Wang. The second is that Tang and Wang’s decomposition is for labour productivity while Diewert (2015) extends the decomposition to MFP.

$$Z^t = \sum_{n=1}^{N} \frac{W_n^t Z_n^t}{W^t} = \sum_{n=1}^{N} w_n^t Z_n^t$$

where $w_n^t = \frac{W_n^t}{W^t}$ is the relative price of the input of sector n.

Each industry has an MFP index, X_n^t, which is given by the ratio of output in the industry to its input index:[9]

$$X_n^t = \frac{Y_n^t}{Z_n^t}$$

Aggregate economy MFP is given by:

$$X^t = \frac{Y^t}{Z^t}$$

Aggregate output and input can be expanded into sums of output and input in each sector weighted by relative prices:

$$X^t = \frac{\sum_{n=1}^{N} p_n^t Y_n^t}{\sum_{n=1}^{N} w_n^t Z_n^t}$$

Multiplying and dividing each term in the numerator by the industry's aggregate input and then the industry's relative input price, we have:

$$X^t = \frac{\sum_{n=1}^{N} p_n^t Z_n^t (Y_n^t / Z_n^t)}{\sum_{n=1}^{N} w_n^t Z_n^t}$$

$$X^t = \frac{\sum_{n=1}^{N} w_n^t (p_n^t / w_n^t) Z_n^t X_n^t}{\sum_{n=1}^{N} w_n^t Z_n^t}$$

Define the share of industry n in economy-wide input costs as:

$$s_{Zn}^t = \frac{W_n^t Z_n^t}{\sum_{n=1}^{N} W_n^t Z_n^t} = \frac{w_n^t Z_n^t}{\sum_{n=1}^{N} w_n^t Z_n^t}$$

Substituting this expression for each sector's input share into our expression for aggregate MFP, we obtain an additively separable decomposition of the aggregate MFP level by sector:

[9] Keep in mind that the composite input Z_n^t is a unit-free index; its absolute level is arbitrary and has no economic meaning. It follows that the same is true of the MFP index X_n^t.

$$X^t = \sum_{n=1}^{N} (p_n^t / w_n^t) X_n^t \, s_{Zn}^t$$

This decomposition has a simple interpretation. The MFP of the aggregate economy is equal to the weighted average of the MFP indexes of each sector adjusted for the relative prices of inputs and outputs in the sector. The weights are simply the share of each input-sector in aggregate input use.

To obtain a decomposition of MFP growth by sector, we can use the above decomposition of the MFP level at time t to express MFP growth as:

$$\frac{X^1}{X^0} = \frac{\sum_{n=1}^{N} (p_n^1 / w_n^1) X_n^1 \, s_{Zn}^1}{\sum_{n=1}^{N} (p_n^0 / w_n^0) X_n^0 \, s_{Zn}^0}$$

For each sector, we can re-express its contribution to MFP at time 1 in terms of its contribution at time 0 multiplied by growth factors for the sector's output price, input price, MFP, and input cost share. This yields

$$\frac{X^1}{X^0} = \frac{\sum_{n=1}^{N} (p_n^1 / p_n^0)(w_n^0 / w_n^1)(X_n^1 / X_n^0)(s_{Zn}^1 / s_{Zn}^0)(p_n^0 / w_n^0) X_n^0 \, s_{Zn}^0}{\sum_{n=1}^{N} (p_n^0 / w_n^0) X_n^0 \, s_{Zn}^0}$$

To complete the decomposition, we need to evaluate the expression:

$$\frac{(p_n^0 / w_n^0) X_n^0 s_{Zn}^0}{\sum_{n=1}^{N} (p_n^0 / w_n^0) X_n^0 \, s_{Zn}^0}$$

Substituting our definitions of MFP and the input share of each industry:

$$\begin{aligned}
\frac{(p_n^0 / w_n^0) X_n^0 s_{Zn}^0}{\sum_{n=1}^{N} (p_n^0 / w_n^0) X_n^0 \, s_{Zn}^0} &= \frac{(p_n^0 / w_n^0)(Y_n^0 / Z_n^0)(w_n^0 Z_n^0 / \sum_{n=1}^{N} w_n^0 Z_n^0)}{\sum_{n=1}^{N} (p_n^0 / w_n^0)(Y_n^0 / Z_n^0)(w_n^0 Z_n^0 / \sum_{i=1}^{N} w_i^0 Z_i^0)} \\
&= \frac{\frac{p_n^0 Y_n^0}{\sum_{n=1}^{N} w_n^0 Z_n^0}}{\sum_{n=1}^{N} \frac{p_n^0 Y_n^0}{\sum_{i=1}^{N} w_n^0 Z_n^0}} \\
&= \frac{p_n^0 Y_n^0}{\sum_{n=1}^{N} p_n^0 Y_n^0} \\
&\equiv s_{Yn}^0
\end{aligned}$$

where s_{Yn}^0 is defined as the share of nominal output in sector n.

Substituting this into the expression for aggregate MFP growth above reveals an additive decomposition of MFP growth by sector:

$$\Gamma \equiv \frac{X^1}{X^0} = \sum_{n=1}^{N} s_{Yn}^0 (p_n^1/p_n^0)(w_n^0/w_n^1)(X_n^1/X_n^0)(s_{Zn}^1/s_{Zn}^0)$$

where Γ is the growth factor of MFP.

The contribution of each sector is proportional to its share of aggregate output and can be broken down into growth in the relative price of the sector, the inverse of growth in the relative input price of the sector, growth in MFP within the sector, and growth in the share of the sector in total input costs.

In practice, it is more convenient to express the decomposition in terms of growth rates. This allows for an additive decomposition which is convenient for assigning a share of the total MFP growth to each factor.

Define the growth rates of relative output prices, (inverse) relative input prices, multifactor productivity, and the input share as follows for each sector:

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

Then we can rewrite our MFP growth decomposition in terms of growth rates as:

$$\boldsymbol{\gamma} = \sum_{\boldsymbol{n=1}}^{\boldsymbol{N}} \boldsymbol{s_{Yn}^0}\{[\mathbf{1} + \boldsymbol{\gamma_n}][\mathbf{1} + \boldsymbol{\rho_n}][\mathbf{1} + \boldsymbol{\omega_n}][\mathbf{1} + \boldsymbol{\sigma_n}] - \mathbf{1}\} \tag{1}$$

where γ is the aggregate MFP growth rate.

Expanding this decomposition, we see that the contribution in each sector is driven by the growth rates of each of our four factors plus their interactions.

$$\gamma = \sum_{n=1}^{N} s_{Yn}^0 \{\gamma_n + \rho_n + \omega_n + \sigma_n + \gamma_n\rho_n + \gamma_n\omega_n + \gamma_n\sigma_n + \rho_n\omega_n + \rho_n\sigma_n + \omega_n\sigma_n + \gamma_n\rho_n\omega_n + \gamma_n\rho_n\sigma_n + \gamma_n\omega_n\sigma_n + \rho_n\omega_n\sigma_n + \gamma_n\rho_n\omega_n\sigma_n\}$$

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 suggest that the contributions of each of the four factors can be assessed by equally allocating each interaction term among its component factors. For example, the contribution of within-sector MFP growth to aggregate MFP growth can be estimated as:

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

Analogous expressions are used for the contributions of output price growth (Δp), (inverse) input price growth (Δw), and input cost share growth (Δs_Z). Then aggregate MFP growth is given by:

$$\gamma = \Delta X + \Delta p + \Delta w + \Delta s_Z$$

B. Traditional Decomposition

The GEAD differs from the traditional decomposition of Denison (1962) by including changes in relative prices. Diewert (2015) finds that, in practice, the price and input share terms of the GEAD for MFP are more or less offsetting in the aggregate so that almost all of aggregate MFP growth can be traced to within-sector growth.[10] However, the decision to include or exclude relative price changes can significantly change the contribution of any given industry.

If we choose to ignore the two relative price growth terms (i.e. to set $\rho_n = 0$ and $\omega_n = 0$ for all industries), then the GEAD decomposition by industry contribution simplifies to:

$$\gamma = \sum_{n=1}^{N} s_{Yn}^{0} \{\gamma_n + \sigma_n + \gamma_n \sigma_n\}$$

This expression is similar to a traditional decomposition, but it still includes price changes in the growth of each sector's share in total (nominal) input costs and the relative price level of the industry in the initial output share, as we have defined σ_n (the growth rate of s_{Zn}^{t}) and s_{Yn}^{0} in terms of nominal values of input and output.

Since we do not wish to include relative prices in the traditional decomposition, we replace the nominal share of aggregate input costs, s_{Zn}^{t}, associated with each industry with the real share of aggregate input use, $\hat{s}_{Zn}^{t}$:

$$\hat{s}_{Zn}^{t} = \frac{Z_n^t}{\sum_{n=1}^{N} Z_n^t}$$

Similarly, we replace s_{Yn}^{0} with $\hat{s}_{Yn}^{0}$, sector n's share of real output in the aggregate economy:[11]

[10] Diewert (2016) provides a mathematical explanation for this.

[11] Note that $\hat{s}_{Yn}^{0} = s_{Yn}^{0}$ if nominal output is equal to real output at time 0. This will occur if output is measured in time 0 constant prices or if time 0 is the reference period for a chained volume measure of output.

$$\hat{s}^0_{Yn} = \frac{Y^0_n}{\sum_{n=1}^{N} Y^0_n}$$

Through these terms, the decomposition rests on the assumption that real aggregate output is equal to the sum of the real outputs of each sector (i.e. $Y^t = \sum_{n=1}^{N} Y^t_n$). This additivity property holds if output is measured with constant prices in a fixed-base Laspeyres framework (Reinsdorf, 2015). Non-additivity arises when chained Fisher output measures are used because this assumption does not hold. Application of the decomposition to MFP requires a similar assumption that real aggregate input is equal to the sum of the real inputs of each sector (i.e. $X^t = \sum_{n=1}^{N} X^t_n$). This will hold if input is measured with constant prices in a fixed-base Laspeyres framework, but not when chained Fisher input measures are used.

Let $\hat{\sigma}_n$ denote the growth rate of sector n's share of aggregate real input. The "traditional" decomposition of MFP growth by sector is thus:[12]

$$\gamma = \sum_{n=1}^{N} \hat{s}^0_{Yn}\{\gamma_n + \hat{\sigma}_n + \gamma_n \hat{\sigma}_n\} \tag{2}$$

This decomposition is relatively simple, with only three terms for each industry:

- The **within-sector effect**: $s^0_{Yn}\gamma_n$;
- The **reallocation level effect**: $s^0_{Yn}\hat{\sigma}_n$;
- And the **reallocation growth effect**: $\hat{s}^0_{Yn}\gamma_n\hat{\sigma}_n$

The within-sector effect represents the contribution from changes in multifactor productivity within industry n. The reallocation level effect captures the contribution of a rising share of input use in sector n. The reallocation growth effect captures how rising productivity within-sector n amplifies any change in the input share of the sector.

There remains disagreement among experts as to whether price changes should be included when decomposing productivity growth. Dumagan (2013) argues that prices should be included because the GEAD is exactly additive in some contexts in which the traditional decomposition is not and that the resulting industry contributions are, in some sense, analytically purer. In particular, Dumagan points out that the within-sector effects of the traditional decomposition are implicitly deflated by an aggregate price index (while the equivalent GEAD within-sector effect is not) so that it does not "purely" represent a "within-sector" effect. However, Reinsdorf (2015) shows that it is possible to modify the traditional approach to achieve exact additivity and that the GEAD of labour productivity provided by Tang and Wang (2004) and the traditional decomposition of labour productivity provide the same within-sector

[12] This decomposition takes the same form as the traditional decomposition of labour productivity growth used in the literature, except that we have replaced labour with some composite measure of total input.

effects (but not the same reallocation effects) if an appropriate base period for the prices is chosen.[13]

In practice, whether a researcher should include price changes in the decomposition of aggregate productivity growth into sectoral contributions depends on what the researcher is interested in understanding. Reinsdorf (2015) argues that including price changes is inconsistent with a concept of productivity growth as an outward movement in the production possibility frontier generated by technological improvements. Including relative price changes can lead to estimates of large contributions to productivity due to surging prices even if there is no change in real output per unit of input within the sector. However, if one is interested in understanding how the value of output generated in the economy per unit of input is changing through time, then accounting for changes in prices is important because they capture the relative values of different forms of output. From the point of view of maximizing the total value of output produced per unit of input, it does not matter whether resources are reallocated to industries that produce output with a relatively high market price (with identical physical productivity) or the relative prices of industries using a greater share of inputs rise (again, holding physical productivity constant). In both cases, the value of output produced per unit of input has increased.

C. CSLS Decomposition

A weakness of the traditional decomposition and of the GEAD is that the apportionment of the total reallocation effect across sectors is problematic. In particular, the reallocation effects are such that a sector will have a positive total reallocation effect as long as the input share of the sector increases. Even if the sector has the lowest productivity level in the economy, an increase in its share of total input costs is interpreted as a positive contribution to aggregate productivity growth. The CSLS decomposition proposes an alternative definition of sectoral reallocation effects that addresses this weakness. In our view, the resulting sectoral contributions to productivity growth are more reasonable and more consistent with economic intuition than the contributions generated by the other decomposition formulas. 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.[14]

To derive the CSLS decomposition, we rewrite the traditional decomposition into a different form. To do so, we will need to rewrite the reallocation level effect. First, we write it out in full:

$$\hat{s}_{Yn}^{0}\hat{\sigma}_n = \left(\frac{Y_n^0}{\sum_{n=1}^{N} Y_n^0}\right)\left(\frac{\hat{s}_{zn}^{1} - \hat{s}_{zn}^{0}}{\hat{s}_{zn}^{0}}\right)$$

[13] While the within-sector effects will be the same, the reallocation effects, and hence the total contribution of each industry, can be very different between the two decompositions.

[14] We proceed by modifying the "traditional decomposition" from the previous section. One could also directly derive the CSLS multifactor productivity decomposition by proceeding in the same manner as used to derive the CSLS labour productivity decomposition (in de Avillez, 2012, for example) but by substituting aggregate input for labour in the derivation. The extension is very straightforward as only the input of interest has changed.

Substituting the definition of s_{zn}^0 yields:

$$\hat{s}_{Yn}^0 \hat{\sigma}_n = \left(\frac{Y_n^0}{\sum_{n=1}^N Y_n^0}\right)\left(\frac{Z_n^0}{\sum_{n=1}^N Z_n^0}\right)^{-1} (\hat{s}_{zn}^1 - \hat{s}_{zn}^0)$$

This can be rewritten as:

$$\hat{s}_{Yn}^0 \hat{\sigma}_n = \left(\frac{Y_n^0}{Z_n^0}\right)\left(\frac{\sum_{n=1}^N Y_n^0}{\sum_{n=1}^N Z_n^0}\right)^{-1} (\hat{s}_{zn}^1 - \hat{s}_{zn}^0)$$
$$\hat{s}_{Yn}^0 \hat{\sigma}_n = \left(\frac{\hat{X}_n^0}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0)$$

Here $\hat{X}_n^t = \frac{Y_n^t}{Z_n^t}$ and $\hat{X}^t = \frac{\sum_{n=1}^N Y_n^t}{\sum_{n=1}^N Z_n^t}$ represent multifactor productivity at time t based upon "real" output and input as measured with a fixed set of constant prices or based on chained aggregation.[15]

This expression tells us that the reallocation level effect is equal to the change in an industry's input share multiplied by the multifactor productivity of that industry relative to the multifactor productivity of the total economy at time 0.

Substituting this expression into the traditional formula we obtain:

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

which is equal to:

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

If we combine the last two terms, we obtain an expression for the total reallocation effect of each industry:

$$\left(\frac{\hat{X}_n^1}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0)$$

Since the ratio of $\left(\frac{\hat{X}_n^1}{\hat{X}^0}\right)$ is positive, a rising input share in an industry will always lead to a positive reallocation effect. Intuitively, this does not seem like a desirable property. One option

[15] Note that $\hat{X}_n^t = X_n^t$, but we introduce the additional notation to avoid confusion as to whether the industry productivity levels are in real terms. Similarly, we write $\hat{\gamma}_n$ for the industry MFP growth rate, although it is identical to γ_n.

would be to forget about assigning reallocation effects to each industry and simply report a total reallocation effect.

Alternatively, we can argue that there is a sensible way to assign the consequences of reallocation to specific industries. Reinsdorf and Yuskavage (2010) suggest that a useful way to think about the reallocation of labour is to view an industry which loses labour as placing it into a pool where it can be drawn upon by all industries. An industry which gains labour takes it out of the pool. The opportunity cost of labour can be viewed as the average productivity of labour in the total economy. The CSLS decomposition proposes that the effects of reallocating resources to or from a sector should be based upon the productivity level of that sector relative to that of the total economy. If the input share of a sector rises, it contributes to productivity growth to the extent that the sector has above average productivity. If the sector has below average productivity, rising employment in that sector will be deemed to have a negative effect on productivity. The way in which reallocations effects are assigned to industries by the CSLS and GEAD decompositions is summarized by Figure 1.

While we believe that the reallocation effects of the CSLS decomposition provide a more relevant approach to understanding the contributions to productivity growth associated with the reallocation of resources into or away from an industry, it is imperfect. One criticism is that reallocation of resources from a sector with very low productivity to another low (below average) productivity sector with higher productivity would result in a negative reallocation level effect attributed to the sector with the higher productivity (because it is below average). While we acknowledge this limitation, we still believe that the CSLS reallocation effect is more informative that the traditional reallocation effect.[16]

The traditional decomposition specified above can easily be modified into a CSLS decomposition. To do so, we will subtract the following two terms, which both sum to zero, from the traditional decomposition formula:[17]

$$\sum_{n=1}^{N}\left(\frac{\hat{X}^0}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0)$$

$$\sum_{n=1}^{N}\left(\frac{\hat{X}^1 - \hat{X}^0}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0)$$

[16] See the appendix for a discussion of an alternative approach to distributing the reallocation effect among industries which would address this criticism. Implementation of that alternative approach would require data on bilateral input flows between sectors, which are generally not available. Baldwin and Willox (2016) present a labour productivity growth decomposition in which labour share gains in one industry are assumed to flow from other industries in proportion to those industries' initial labour shares. As it turns out, the Baldwin-Willox decomposition's total reallocation effect is, to a close approximation, a version of the CSLS decomposition's reallocation level effect.

[17] These terms sum to zero provided that the input shares sum to 1 in both periods, which they do above because of how we have defined them. However, if we formally derived the CSLS / traditional decompositions of MFP in the same manner as the CSLS / traditional decompositions of labour productivity are typically derived in the literature, we would require an assumption that the sum of the real inputs from each sector is equal to aggregate input. Using chained Fisher data, this assumption is violated, leading to input shares which do not sum exactly to 1 and make the decomposition not exactly additive.

Figure 1: Directions of Reallocation Contribution for Above and Below Average Productivity Sectors, GEAD and CSLS Decompositions

	CSLS		GEAD	
	Rising Input Share	Declining Input Share	Rising Input Share	Declining Input Share
Above Average Productivity	+	−	+	−
Below Average Productivity	−	+	+	−

This results in the CSLS decomposition of MFP growth:

$$\hat{\gamma} = \sum_{n=1}^{N} \hat{s}_{Yn}^{0} \hat{\gamma}_n + \left(\frac{\hat{X}_n^0 - \hat{X}^0}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0) + \left(\frac{(\hat{X}_n^1 - \hat{X}_n^0) - (\hat{X}^1 - \hat{X}^0)}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0) \quad (3)$$

This expression looks similar to the CSLS decomposition of labour productivity growth (de Avillez, 2012). This should not be surprising, as the only difference between MFP and a partial productivity measure such as labour productivity is the measure of input used (a single input or an aggregate of multiple inputs). Indeed, if we restrict ourselves to one input, this expression provides the partial productivity decompositions for that input. Like the traditional decomposition, the CSLS decomposition has a within-sector effect, a reallocation level effect and a reallocation growth effect.

The appendix of this report extends the CSLS decomposition and the GEAD to allow for contributions from each sector to be assigned to specific inputs.

D. Data

We implement the GEAD (equation (1)) and the CSLS decomposition (equation (3)) of MFP growth for "business sector industries" in Canada over the 1997-2014 period.[18] 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.[19] Using these data at

[18] 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.'

[19] 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.

the industry-province level, we construct aggregates at the provincial level (i.e. 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).[20] 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-province pairs even in the reference year, with all MFP levels expressed relative to that 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.[21]

III. Results

A. Overview of MFP Growth by Province and Industry

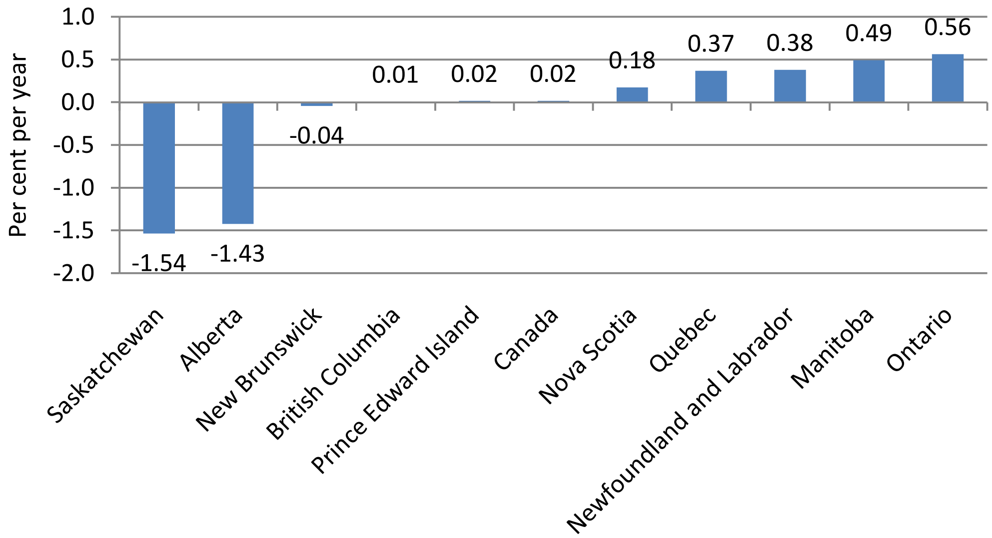
Before presenting the results of our decompositions, it is informative to discuss the underlying trends in each sector (industry-province pair) of the economy. Since the GEAD breaks MFP growth into contributions related to changes in MFP within each sector, the input and output prices of the sector, 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

[20] 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.

[21] 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.

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.

Canada's official estimates for the aggregate business sector (depicted in Chart 1 at the beginning of this report) 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.[22]

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.[23]

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.[24]

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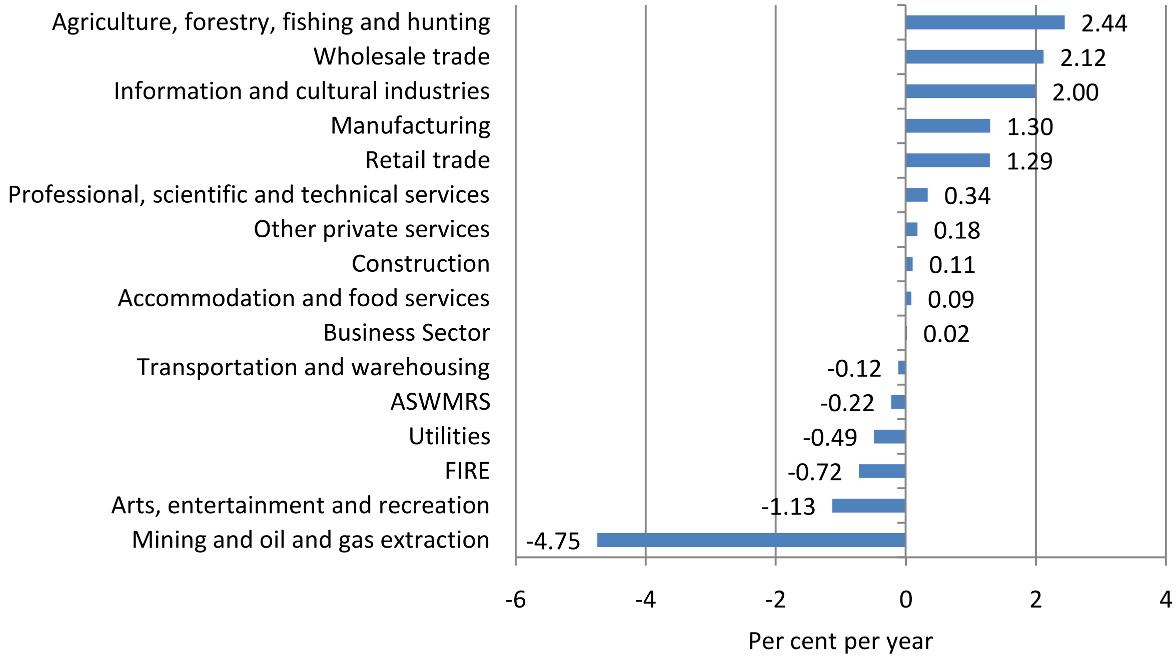
[22] In particular, the national MFP program includes land and inventories as components of the capital stock and accounts for tax parameters in the estimation of user costs. The provincial capital services data do not account for these factors. See Gu and Lee (2013).

[23] 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.

[24] 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

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.

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 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.

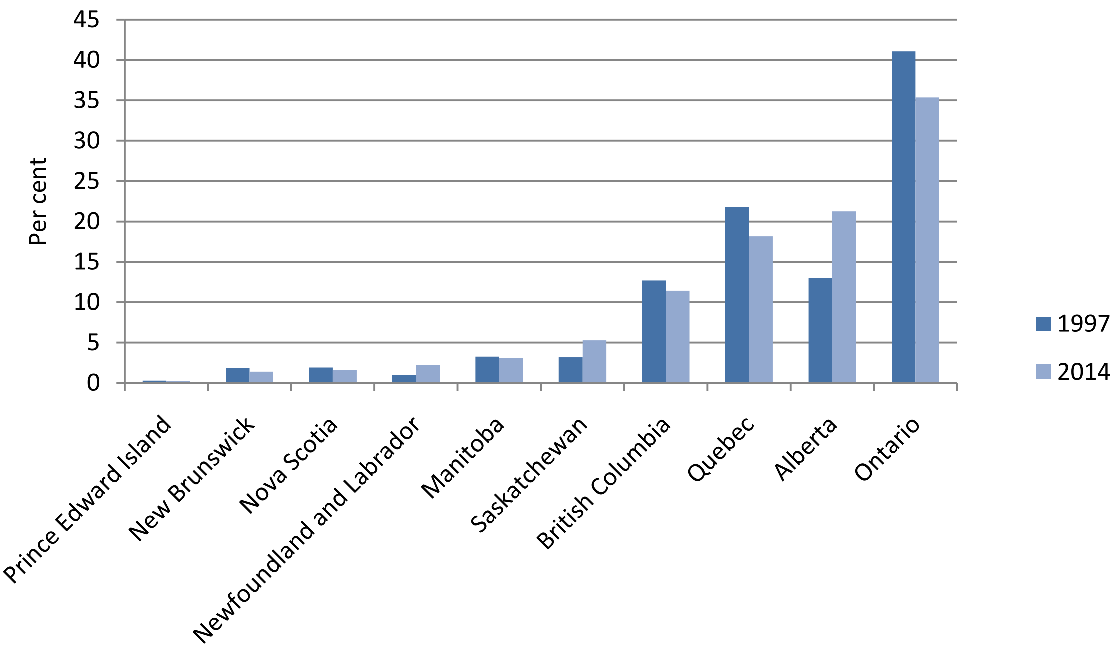
pace than that observed in Alberta and Saskatchewan over the 1997-2014 period. MFP growth was strong in mining and oil and gas extraction in the province because capital input growth was limited while output significantly increased, likely due to increased capacity utilization of the new offshore wells. 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).

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.[25]

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

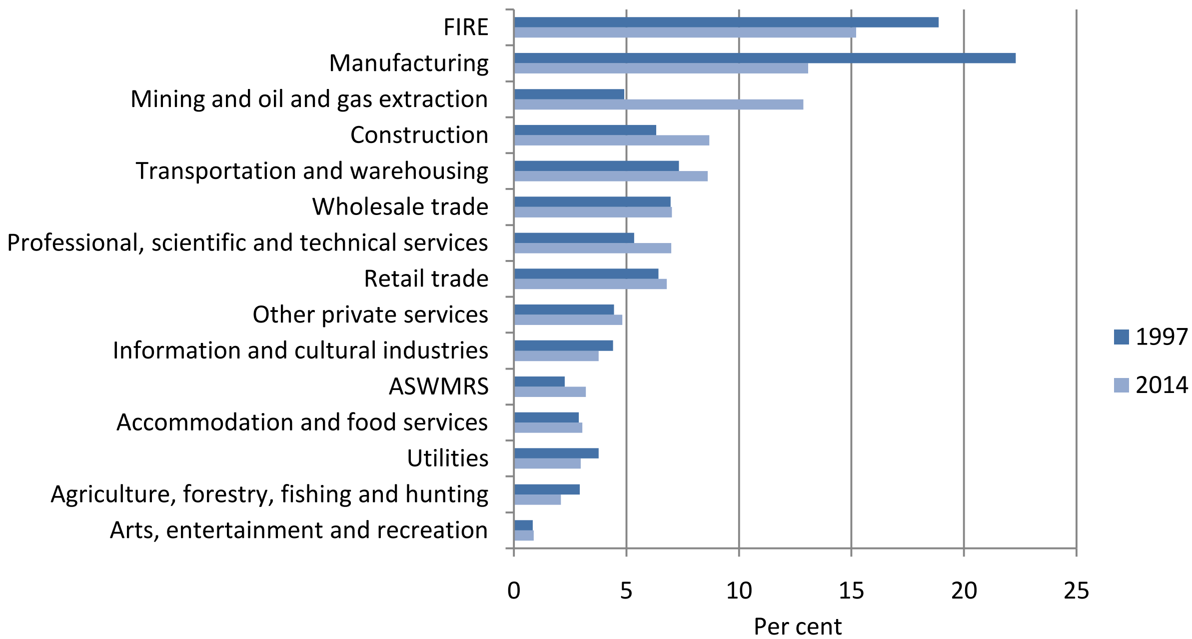
Chart 4: Distribution of Nominal Input Costs Across Provinces, Per Cent, 1997 and 2014



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

[25] 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 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.

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. 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.[26] In the GEAD, the rising relative price of mining and oil and gas sector output and the falling relative price of manufacturing sector output will provide a countervailing force. We now examine these price changes in more detail.

B. Output and Input Prices

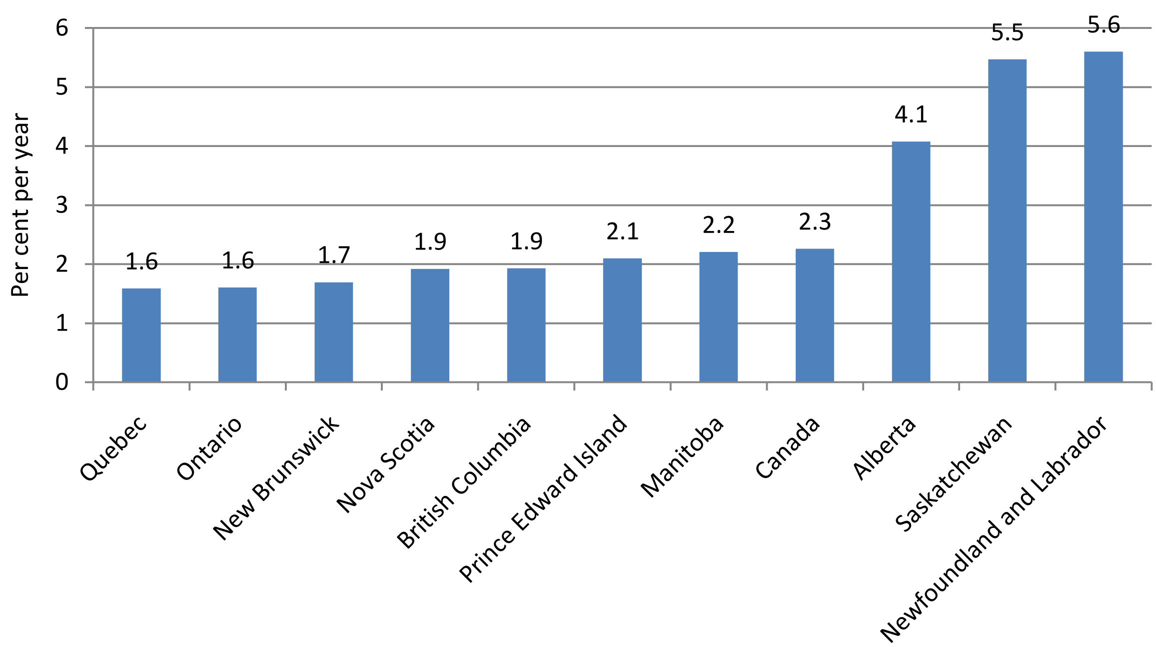
If the output of a sector becomes more valuable relative to that of other sectors over time, reflected in a rising relative price of the output of the sector, then the GEAD ascribes a larger

[26] 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.

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.

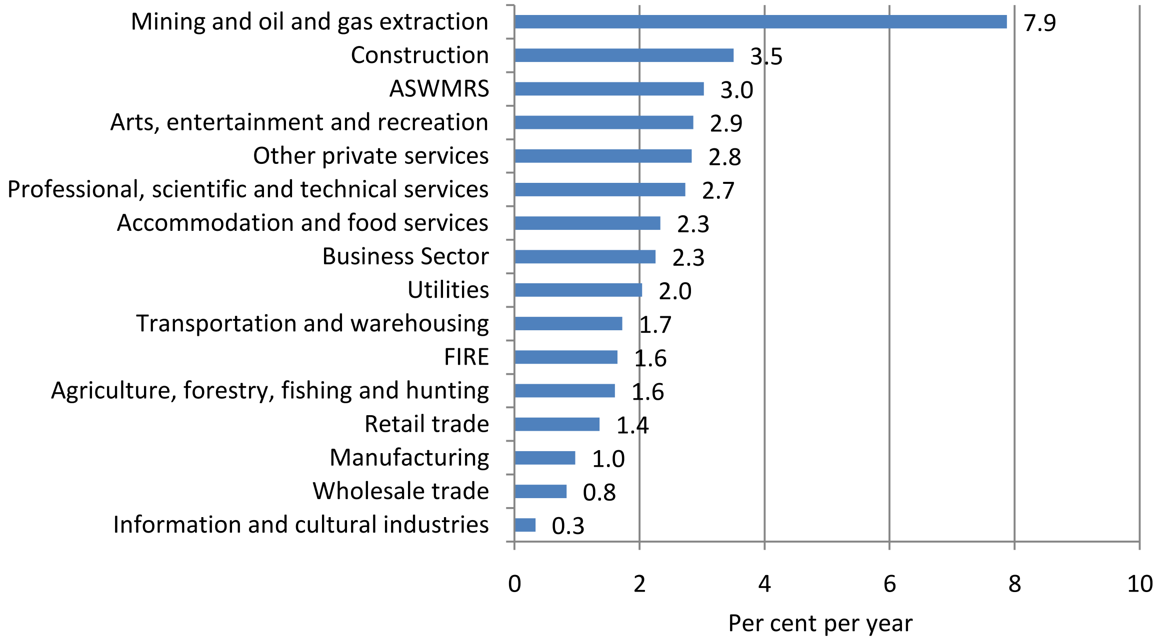
At 7.9 per cent per year, output price growth in mining and oil and gas extraction was more than double the next highest output price growth rate among the fifteen business sector industries over the 1997-2014 period (Chart 7). As we shall see, this will translate into large MFP growth contributions 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).

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.

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.

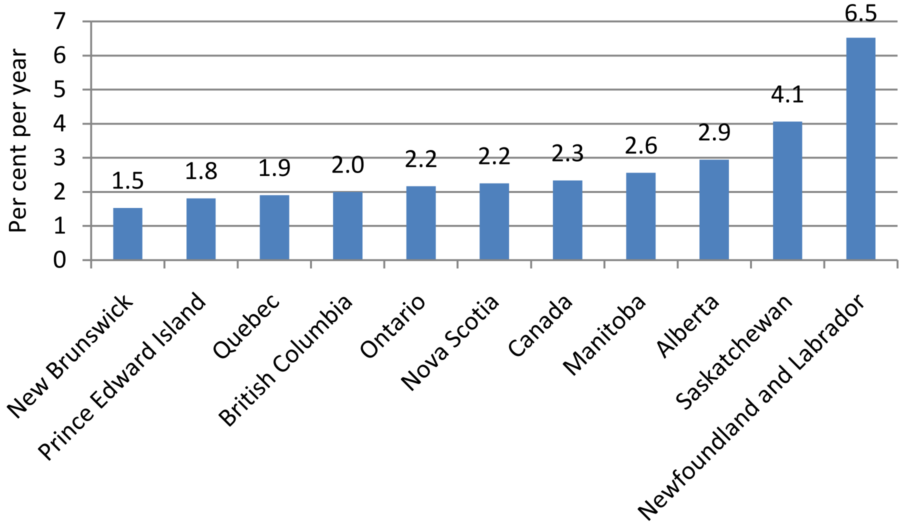
Note: FIRE = Finance, insurance, and real estate. ASWMRS = administration and support, waste management and remediation services.

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 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).

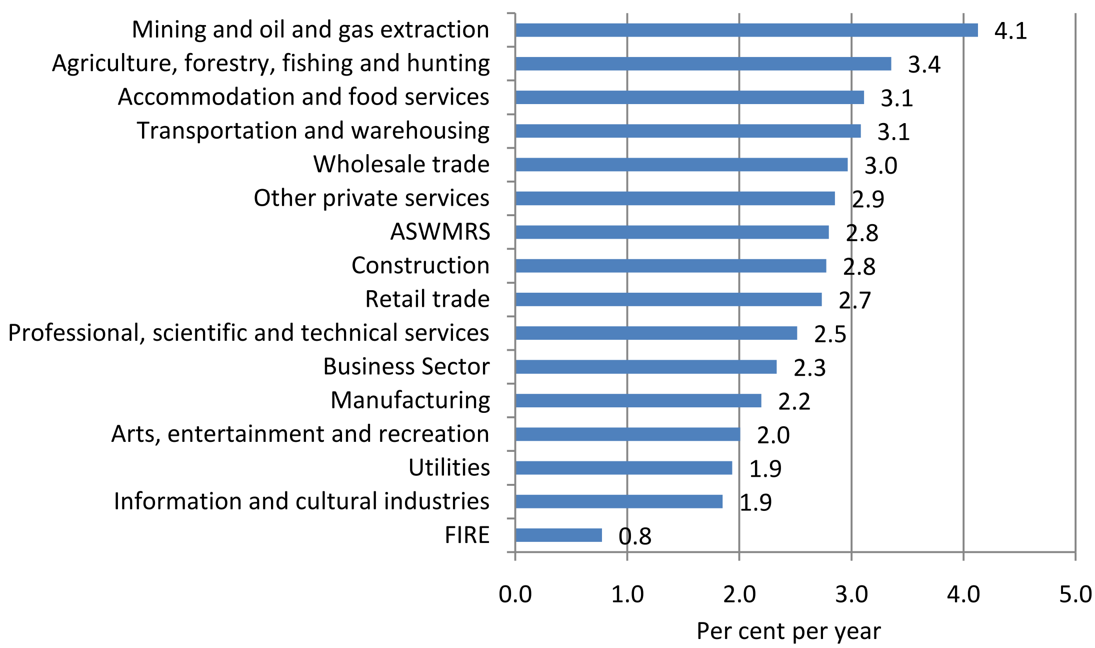
Given the provincial patterns, it is unsurprising that the fastest input price growth among industries occurred in mining and oil and gas extraction, at 4.1 per cent per year (Chart 9). The slowest input price growth over the 1997-2014 period was in FIRE (0.8 per cent per year).

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.

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.

C. 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.[27]

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 output 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 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 in those 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.

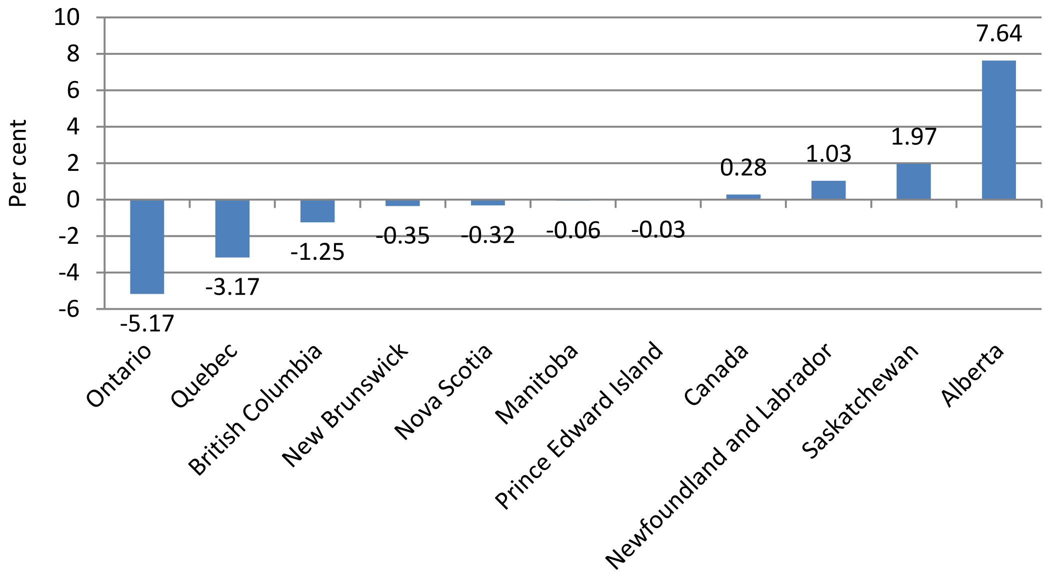
[27] Recall that each of the four components contains an equal share of the factor's interaction effects with the other factors.

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
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
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.

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



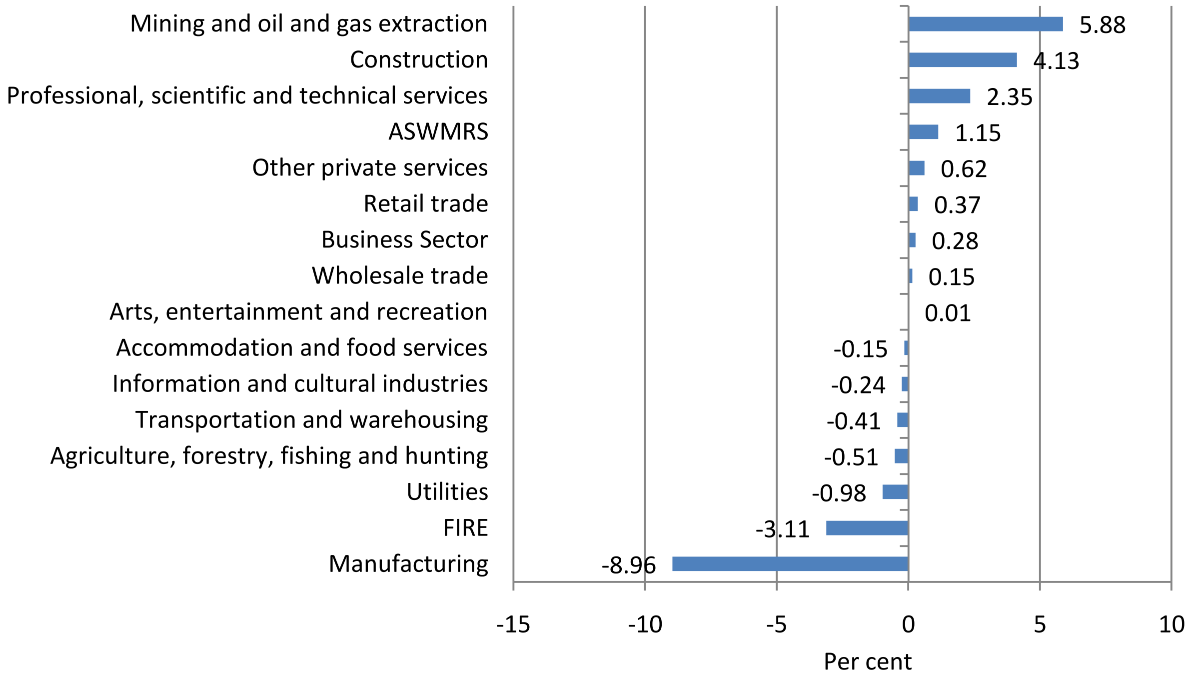
Source: Authors' calculations based on data from CANSIM Table 383-0026.

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 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.

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.

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 average annual 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 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 estimate in Canada. Diewert also estimates 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.

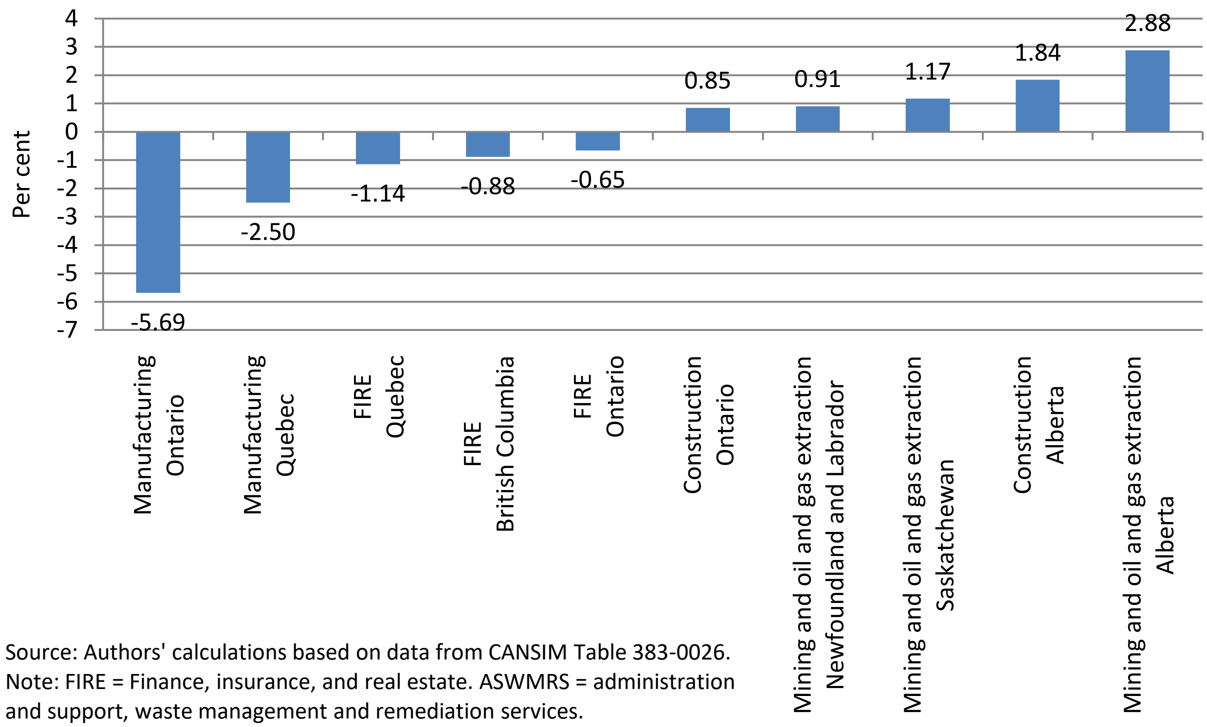
Table 2: Ten Largest Positive and Negative Province-Industry Contributions to Multifactor Productivity Growth in Canada, GEAD, Percentage Points, 1997-2014

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.

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.

Chart 12: Five Largest Positive and Negative Province-Industry Contributions 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.

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 (Chart 12), 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.

Table 3 reveals that 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.

Table 3: Contributions of Alberta Business Sector Industries to Multifactor Productivity Growth in Canada, GEAD, Percent of Alberta's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Effect
Alberta	-53.84	70.11	-34.14	117.87	100.00
Accommodation and food services	0.22	0.78	-1.86	2.28	1.42
ASWMRS	0.62	1.25	-2.33	4.69	4.24
Agriculture, forestry, fishing and hunting	2.84	-0.03	-1.91	-0.72	0.19
Arts, entertainment and recreation	-0.44	0.17	0.14	0.33	0.20
Construction	4.14	6.68	-9.68	22.90	24.04
FIRE	-6.20	-1.22	7.90	0.04	0.53
Information and cultural industries	1.49	-0.99	0.14	0.55	1.18
Manufacturing	1.94	1.92	-4.49	1.17	0.55
Mining and oil and gas extraction	-65.43	55.27	-9.12	57.05	37.77
Other private services	1.83	1.59	-3.33	4.36	4.45
Professional, scientific and technical services	3.35	3.10	-3.39	7.17	10.23
Retail trade	4.57	-0.81	-3.44	4.79	5.11
Transportation and warehousing	-1.29	1.11	-3.24	7.63	4.21
Utilities	-3.86	1.09	2.19	0.96	0.39
Wholesale trade	2.37	0.20	-1.72	4.66	5.51

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.

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 (Table 4). 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.[28] 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).

[28] 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 4: Contributions of Ontario Business Sector Industries to Multifactor Productivity Growth in Canada, GEAD, Percent of Ontario's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Effect
Ontario	-75.16	82.09	-22.13	115.20	100.00
Accommodation and food services	-0.63	0.15	1.13	0.34	0.99
ASWMRS	3.49	-2.62	-0.42	-7.92	-7.46
Agriculture, forestry, fishing and hunting	-4.77	1.99	1.87	3.62	2.71
Arts, entertainment and recreation	0.70	-0.38	-0.14	0.53	0.72
Construction	6.10	-12.86	-3.56	-6.12	-16.44
FIRE	4.35	11.79	-23.06	19.52	12.60
Information and cultural industries	-10.84	10.59	-3.68	2.97	-0.96
Manufacturing	-46.12	47.74	-9.34	117.71	109.99
Mining and oil and gas extraction	8.65	-8.44	3.00	-6.29	-3.09
Other private services	-0.31	-0.90	2.79	-2.29	-0.70
Professional, scientific and technical services	-1.29	-1.11	-0.87	-12.15	-15.42
Retail trade	-8.18	8.81	-0.08	0.79	1.34
Transportation and warehousing	3.23	3.07	2.95	-5.90	3.35
Utilities	-0.52	4.79	-1.67	9.00	11.61
Wholesale trade	-29.02	19.47	8.94	1.37	0.76

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.

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 (Table 5). 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 Labrador, which together account for 84.4 per cent of the industry's total effect (Table 6). 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.

Table 5: Contributions of Manufacturing to Canada's Multifactor Productivity Growth by Province, GEAD, Percent of Manufacturing's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Effect
Manufacturing	-44.0	43.3	-6.0	106.7	100.0
Alberta	-1.65	-1.64	3.82	-0.99	-0.46
British Columbia	-6.11	5.01	-0.21	8.38	7.07
Manitoba	-0.69	0.04	0.41	1.10	0.86
New Brunswick	0.18	0.56	-0.97	1.54	1.32
Newfoundland and Labrador	-0.04	0.02	-0.14	0.40	0.23
Nova Scotia	-0.60	0.17	0.45	0.90	0.92
Ontario	-26.63	27.57	-5.39	67.97	63.51
Prince Edward Island	-0.07	0.11	-0.08	0.05	0.02
Quebec	-7.66	12.41	-5.47	28.59	27.87
Saskatchewan	-0.76	-0.99	1.62	-1.21	-1.34

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

Table 6: Contributions of Mining and Oil and Gas Extraction to Canada's Multifactor Productivity Growth by Province, GEAD, Percent of the Mining and Oil and Gas Extraction Industry's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Effect
Mining and oil and gas extraction	-138.1	153.4	-72.8	157.4	100.0
Alberta	-85.02	71.82	-11.86	74.13	49.08
British Columbia	-7.12	6.10	-3.32	11.47	7.13
Manitoba	-2.23	3.49	-2.55	3.73	2.44
New Brunswick	-1.61	1.73	-0.36	0.36	0.13
Newfoundland and Labrador	10.41	17.24	-35.45	23.22	15.42
Nova Scotia	0.11	-0.36	0.01	-0.24	-0.48
Ontario	-7.62	7.44	-2.64	5.54	2.72
Prince Edward Island	-0.01	0.01	0.00	0.00	0.00
Quebec	-4.16	6.00	-4.11	5.92	3.65
Saskatchewan	-40.86	39.95	-12.48	33.29	19.91

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

D. Decomposition Results: CSLS Decomposition

Table 7 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

Table 7: Contributions by Provinces and Business Sector Industries to Multifactor Productivity Growth in Canada, 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
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
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.

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.

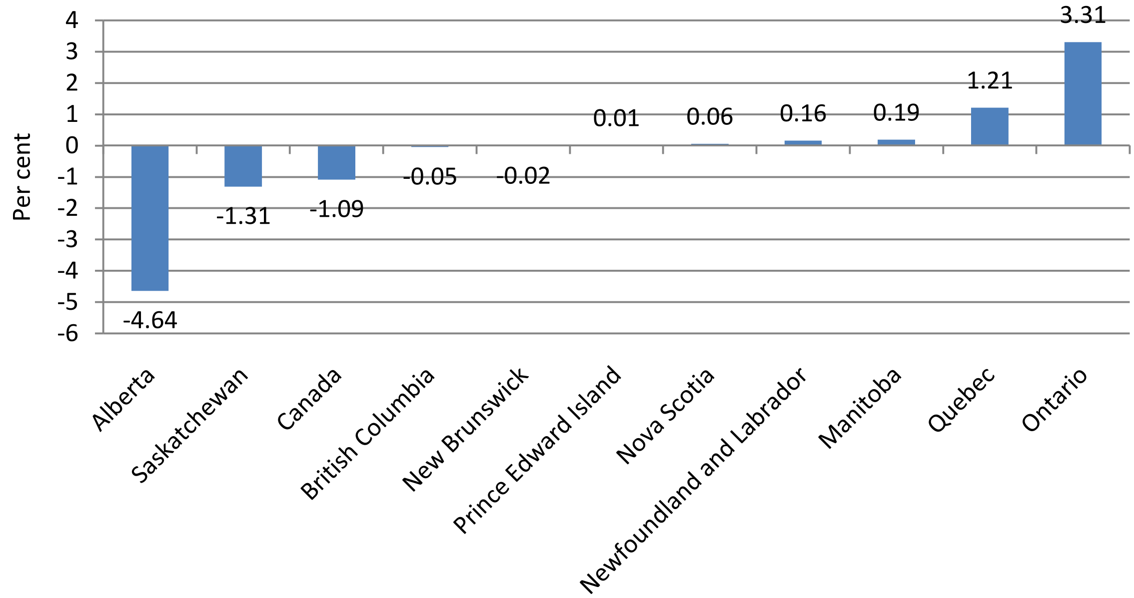
First, we consider MFP growth at the aggregate level.[29] Within-sector MFP growth contributed 2.2 percentage points to overall MFP growth. An additional contribution of 8.1 percentage points arose from the reallocation level effect. This reflects the movement of resources into Canada's mining and oil 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 13). 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 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 14).

As Table 7 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

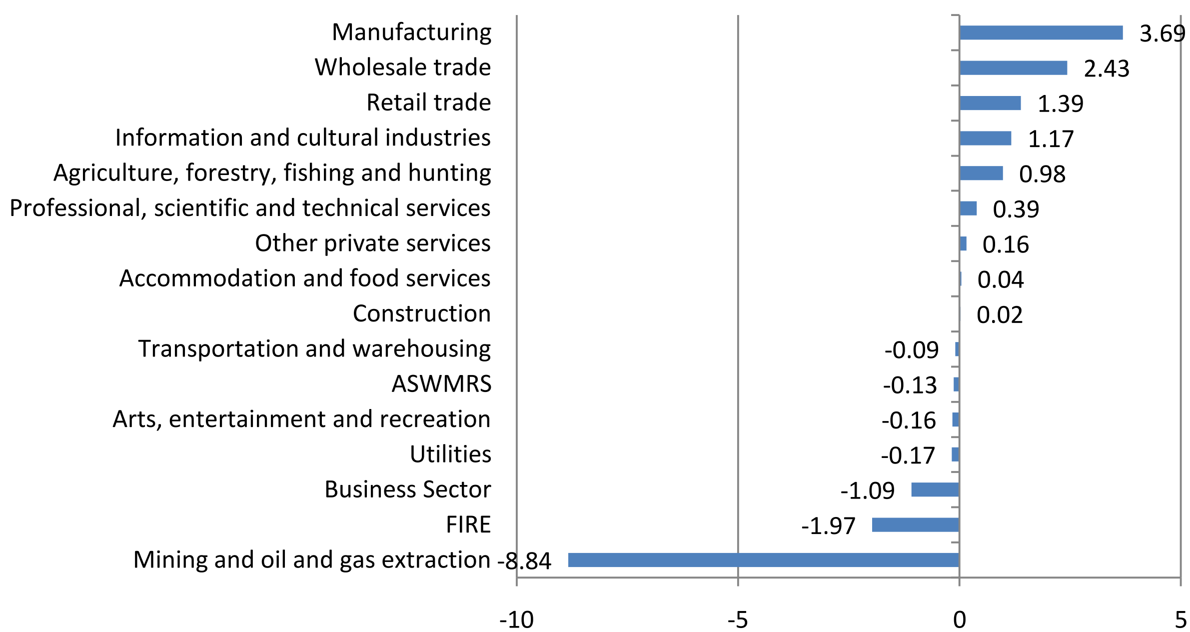
[29] Note that the economy-wide total effect in Table 7 is -1.09 per cent between 1997 and 2014. This differs from the cumulative aggregate MFP growth of 0.28 per cent displayed in Table 1 and in Chart 2. This discrepancy arises from the fact that the CSLS decomposition does not satisfy exact additivity; 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 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 13: Contributions by Provinces to Multifactor Productivity Growth in Canada, CSLS Decomposition, Percentage Points, 1997-2014



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

Chart 14: Contributions by Business Sector Industries to Multifactor Productivity Growth in Canada, 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.

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 CSLS and GEAD decompositions generally agree about the sizes of the major within-sector effects.[30] 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 14). 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 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 8 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 (Chart 15). 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.

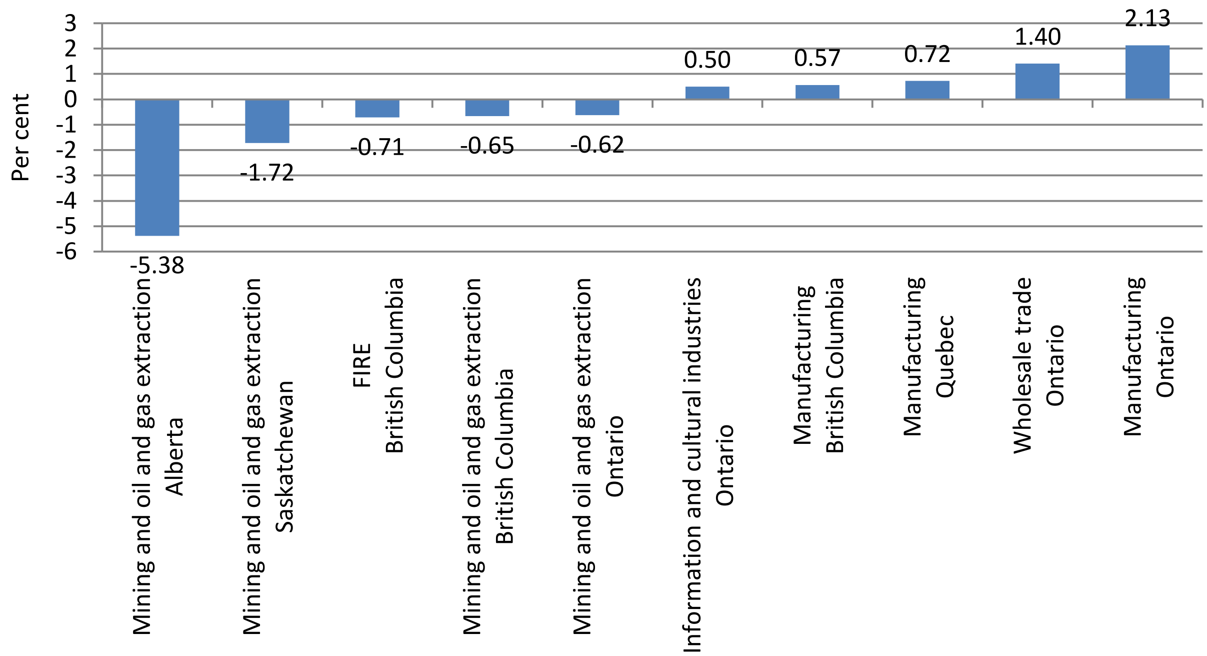
[30] The within-sector effects of the two decompositions differ for two reasons. The first is the choice of reference year used for our indexes. We use 2007, the reference year used by Statistics Canada, but the CSLS decomposition and the GEAD should only be expected to yield the same within-sector effects if the reference year for prices corresponds to the first year of the period over which productivity growth is being considered (1997). Second, our GEAD within-sector effect includes interaction terms with prices and input share growth while the CSLS within-sector effect does not.

Table 8: Ten Largest Positive and Negative Province-Industry Contributions to Multifactor Productivity Growth in Canada, 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.

Chart 15: Five Largest Positive and Negative Province-Industry Contributions to Multifactor Productivity Growth in Canada, 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.

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 (Table 9). The next largest contribution in the province was from FIRE, which 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.

Table 9: Contributions of Alberta Business Sector Industries to Canada's Multifactor Productivity Growth, CSLS Decomposition, Percent of Alberta's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Reallocation Level Effect	Reallocation Growth Effect	Total Effect
Alberta	86.4	-110.6	124.2	100.0
Accommodation and food services	-0.34	0.00	-0.02	-0.36
ASWMRS	-0.75	0.49	-0.30	-0.56
Agriculture, forestry, fishing and hunting	-4.61	-1.37	1.96	-4.02
Arts, entertainment and recreation	0.57	-0.28	0.26	0.55
Construction	-5.16	3.23	-2.84	-4.77
FIRE	7.96	-2.50	2.05	7.51
Information and cultural industries	-2.17	0.17	-0.24	-2.24
Manufacturing	-3.22	0.46	0.46	-2.30
Mining and oil and gas extraction	105.21	-110.24	121.03	116.00
Other private services	-2.72	0.27	-0.31	-2.76
Professional, scientific and technical services	-4.29	1.07	-1.28	-4.50
Retail trade	-6.65	0.62	-0.89	-6.92
Transportation and warehousing	1.57	0.08	1.05	2.69
Utilities	4.43	-2.88	4.11	5.66
Wholesale trade	-3.43	0.30	-0.85	-3.97

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.

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 (Table 10). 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 contributions to Canada's MFP growth over the 1997-2014 period (Table 11). 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.

Table 10: Contributions of Ontario Business Sector Industries to Canada's Multifactor Productivity Growth, CSLS Decomposition, Percent of Ontario's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Reallocation Level Effect	Reallocation Growth Effect	Total Effect
Ontario	130.9	29.3	-60.2	100.0
Accommodation and food services	1.04	-0.03	-0.09	0.93
ASWMRS	-4.51	0.64	-1.26	-5.13
Agriculture, forestry, fishing and hunting	7.87	2.00	-3.50	6.37
Arts, entertainment and recreation	-1.07	-0.09	0.07	-1.09
Construction	-8.15	-1.10	-1.25	-10.50
FIRE	-6.59	0.44	-0.13	-6.28
Information and cultural industries	14.78	-0.10	0.30	14.98
Manufacturing	87.06	19.03	-41.54	64.55
Mining and oil and gas extraction	-16.24	2.55	-5.00	-18.70
Other private services	0.49	-0.04	-0.01	0.45
Professional, scientific and technical services	1.74	0.05	0.40	2.19
Retail trade	12.86	0.21	-0.26	12.81
Transportation and warehousing	-4.54	0.14	-0.52	-4.92
Utilities	0.84	1.24	-0.21	1.87
Wholesale trade	45.36	4.34	-7.22	42.48

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.

Table 11: Contributions of Manufacturing to Canada's Multifactor Productivity Growth by Province, CSLS Decomposition, Percent of Manufacturing's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Reallocation Level Effect	Reallocation Growth Effect	Total Effect
Manufacturing	124.9	28.0	-52.9	100.0
Alberta	4.05	-0.58	-0.57	2.89
British Columbia	16.52	5.36	-6.44	15.43
Manitoba	1.76	0.06	-0.38	1.44
New Brunswick	-0.45	-0.08	0.08	-0.46
Newfoundland and Labrador	0.12	-0.05	-0.03	0.04
Nova Scotia	1.91	0.26	-0.81	1.37
Ontario	77.91	17.03	-37.17	57.77
Prince Edward Island	0.17	0.00	0.01	0.18
Quebec	21.08	5.90	-7.40	19.57
Saskatchewan	1.81	0.15	-0.19	1.76

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

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 (Table 12). 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.

Finally, Table 13 shows the distribution across provinces of the contribution of the FIRE industry to aggregate MFP growth 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.

Table 12: Contributions of Mining and Oil and Gas Extraction to Canada's Multifactor Productivity Growth by Province, CSLS Decomposition, Percent of the Mining and Oil and Gas Extraction Industry's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Reallocation Level Effect	Reallocation Growth Effect	Total Effect
Mining and Oil and Gas	80.2	-69.8	89.6	100.0
Alberta	55.20	-57.84	63.50	60.86
British Columbia	4.30	-2.36	5.47	7.41
Manitoba	1.47	-0.04	0.78	2.21
New Brunswick	0.95	0.00	0.00	0.95
Newfoundland and Labrador	-3.00	3.69	-1.06	-0.37
Nova Scotia	-0.16	-0.16	0.04	-0.27
Ontario	6.08	-0.95	1.87	6.99
Prince Edward Island	0.00	0.00	0.00	0.00
Quebec	2.26	-0.34	0.85	2.76
Saskatchewan	13.11	-11.82	18.17	19.45

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

Table 13: Contributions of Finance, Insurance and Real Estate to Canada's Multifactor Productivity Growth by Province, CSLS Decomposition, Percent of the Finance, Insurance and Real Estate Industry's Total Contribution, 1997-2014

	Within-Sector MFP Growth	Reallocation Level Effect	Reallocation Growth Effect	Total Effect
FIRE	101.5	-7.2	5.8	100.0
Alberta	18.73	-5.88	4.82	17.67
British Columbia	36.20	-0.71	0.67	36.16
Manitoba	3.57	-0.10	0.08	3.55
New Brunswick	2.15	-0.12	0.10	2.13
Newfoundland and Labrador	1.73	0.20	-0.15	1.77
Nova Scotia	4.63	-0.07	0.07	4.62
Ontario	11.05	-0.74	0.22	10.53
Prince Edward Island	1.00	-0.05	0.05	1.00
Quebec	22.71	0.15	-0.10	22.76
Saskatchewan	-0.31	0.08	0.01	-0.21

Source: Authors' calculations based on data from CANSIM Table 383-0026.
Note: FIRE = Finance, insurance, and real estate.

IV. 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 report, 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 paper 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.

References

Almon, Michael-John, and Jianmin Tang (2011) "Industrial Structural Change and the Post-2000 Output and Productivity Growth Slowdown: A Canada-US Comparison," *International Productivity Monitor*, Number 22, Fall, pp. 44-81.

Baldwin, John R., Wulong Gu, Ryan Macdonald, Weimin Wang and Beiling Yan (2014) "Revisions to the Multifactor Productivity Accounts," *Canadian Productivity Review*, No. 035, Catalogue no. 15-206-X.

Baldwin, John R., and Michael Willox (2016) "The Industry Origins of Canada's Weaker Labour Productivity Performance and the Role of Structural Adjustment," *International Productivity Monitor*, Number 31, Fall, pp. xx-xx.

de Avillez, Ricardo (2012) "Sectoral Contributions to Labour Productivity Growth in Canada: Does the Choice of Decomposition Formula Matter?" *International Productivity Monitor*, Number 24, Fall, pp. 97-117.

Denison, Edward F. (1962) The Sources of Economic Growth in the United States and the Alternatives Before Us, New York: Committee for Economic Development.

Diewert, W. Erwin, and Emily Yu (2012) "New Estimates of Real Income and Multifactor Productivity Growth for the Canadian Business Sector, 1961-2011," *International Productivity Monitor*, Number 24, Fall, pp. 27-48.

Diewert, W. Erwin (2015) "Decompositions of Productivity Growth into Sectoral Effects," *Journal of Productivity Analysis*, Vol. 43, No. 3, pp. 367-387.

Diewert, W. Erwin (2016) "Decompositions of Productivity Growth into Sectoral Effects: Some Puzzles Explained," in Greene, W.H., L. Khalaf, R.C. Sickles, M. Veall and M.-C. Voia (eds.) Productivity and Efficiency Analysis, Springer International Publishing.

Dumagan, Jesus C. (2013). "A Generalized Exactly Additive Decomposition of Aggregate Labor Productivity Growth." *Review of Income and Wealth*, Vol. 59, No. 1, pp. 157-168.

Grand'Maison, Etienne, and Andrew Sharpe (2013) "A Detailed Analysis of Newfoundland and Labrador's Productivity Performance, 1997-2010: The Impact of the Oil Boom," CSLS Research Report 2013-05, July.
http://www.csls.ca/reports/csls2013-05.pdf.

Gu, Wulong (2012) "Estimating Capital Input for Measuring Business Sector Multifactor Productivity Growth in Canada: Response to Diewert and Yu," *International Productivity Monitor*, Number 24, Fall, pp. 49-62.

Gu, Wulong, and Beatrix Lee (2013) "Productivity and Economic Growth in the Canadian Provinces, 1997 to 2010," *Canadian Productivity Review*, Catalogue no. 15-206-X — No. 030.

Landefeld, J. Steven, Brent R. Moulton, and Cindy M. Vojtech (2003) "Chained-Dollar Indexes: Issues, Tips on Their Use, and Upcoming Changes," *Survey of Current Business*, Vol. 83, No. 11, pp. 8-16.

Murray, Alexander (2016) "Partial versus Total Factor Productivity Measures: An Assessment of their Strengths and Weaknesses," *International Productivity Monitor*, Number 31, Fall, pp. xx-xx.

Reinsdorf, Marshall, and Robert Yuskavage (2010) "Exact Industry Contributions to Labour Productivity Change," in W.E. Diewert, B.M. Balk, D. Fixler, K.J. Fox and A.O. Nakamura (eds.) Price and Productivity Measurement: Volume 6 - Index Number Theory (Victoria, B.C.: Trafford Press).

Reinsdorf, Marshall (2015) "Measuring Industry Contributions to Labour Productivity Change: A New Formula in a Chained Fisher Index Framework," *International Productivity Monitor*, Number 28, Spring, pp. 3-26.

Sharpe, Andrew (2009) "The Paradox of Market-Oriented Public Policy and Poor Productivity Growth in Canada," in A Festschrift in Honour of David Dodge's Contributions to Canadian Public Policy, Ottawa: Bank of Canada.
http://www.bankofcanada.ca/wp-content/uploads/2010/09/sharpe.pdf

Sharpe, Andrew (2010) "Can Sectoral Reallocations of Labour Explain Canada's Abysmal Productivity Performance?" *International Productivity Monitor*, Number. 19, Spring, pp. 40-49.

Sharpe, Andrew, and Eric Thomson (2010) "Insights into Canada's Abysmal Post-2000 Productivity Performance from Decompositions of Labour Productivity Growth by Industry and Province," *International Productivity Monitor*, Number 20, Fall, pp. 48-67.

Sharpe, Andrew, and Bert Waslander (2014) "The Impact of the Oil Boom on Canada's Labour Productivity Performance, 2000-2012," *International Productivity Monitor*, Number 27, Fall, pp. 40-63.

Solow, Robert M. (1957) "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, Vol. 39, No. 3, pp. 312-320.

Tang, Jianmin, and Weimin Wang (2004) "Sources of Aggregate Labour Productivity Growth in Canada and the United States," *Canadian Journal of Economics*, Vol. 37, No. 2, pp. 421-444.

Appendix

A. An Alternative Approach to Reallocation Effects

The CSLS decomposition does not capture the productivity-enhancing impact of input reallocation from a low-productivity industry to a higher-productivity industry if both industries are of below-average productivity. In this appendix, we briefly discuss how the reallocation effects in the CSLS decomposition might be further refined to avoid this problem.

A useful starting point is to ask how we would like a reallocation of labour from one sector to another to be treated. We assume that productivity is characteristic of the sector, not the individual, so that the individual will have the average productivity of whatever sector he or she is in.[31] If a worker leaves a below average productivity sector and enters a sector with a higher productivity level, both sectors should be considered to have made a non-negative contribution to total productivity, and the sum of the contributions should be equal to the effect of the move on aggregate productivity.[32] Similarly, if a worker leaves a sector to work in another sector with a lower level of productivity, both sectors should be viewed as making non-positive contributions and these contributions should sum to the total effect of the move on aggregate productivity. Both the traditional and CSLS decompositions violate these criteria.

If we possessed data on the flows of workers from one sector to another (and into or out of employment)[33], could we specify reallocation effects which satisfy these criteria? Theoretically, the change in the share of resources allocated to a sector can be decomposed into contributions from the changes in the shares of resources allocated to each of the other sectors. Denote the change in the share of sector n in total input use between periods 0 and 1:

$$\Delta\hat{s}_{zn} = (\hat{s}_{zn}^{1} - \hat{s}_{zn}^{0})$$

Let $\Delta\hat{s}_{znr}$ be the change in the input share of sector n related to changes in the input share of sector r. Note that $\Delta\hat{s}_{zab} = -\Delta\hat{s}_{zba}$ for any two sectors a and b. Also, the sum of the contributions to the change in a sector's input share from all sectors is equal to the total change in an sector's input share:

[31] This assumption is certainly questionable, as one might argue that, in theory, the marginal products will be equalized across sectors in equilibrium so that reallocation of an hour of one hour of work between industries will have no effect on aggregate productivity.

[32] The appropriate way to allocate the contribution across the two sectors is not obvious. Should more weight be given to the sector with the lower productivity level for shrinking or to the higher productivity sector for growing? One option is that the total contribution of the bilateral change should be divided equally among the two sectors.

[33] In practice, the issue is complicated by the fact that the employment shares of each sector are determined not only by flows of workers between sectors, but also by changes in the unemployment rate, the labour force participation rate, the average number of hours worked by a worker within each sector, and changes in the working age population due to migration and aging.

$$\sum_{r=1}^{N} \Delta\hat{s}_{znr} = \Delta\hat{s}_{zn}$$

We can rewrite the total reallocation effect as:

$$\sum_{n=1}^{N} \left(\frac{\hat{X}_n^1}{\hat{X}^0}\right)(\Delta\hat{s}_{zn})$$

$$= \sum_{n=1}^{N}\sum_{r=1}^{R} \left(\frac{\hat{X}_n^1}{\hat{X}^0}\right)(\Delta\hat{s}_{znr})$$

Using $\Delta\hat{s}_{zab} = -\Delta\hat{s}_{zba}$, we have:

$$= \sum_{n=1}^{N}\sum_{r<n} \left(\frac{\hat{X}_n^1}{\hat{X}^0}\right)\Delta\hat{s}_{znr} - \left(\frac{\hat{X}_r^1}{\hat{X}^0}\right)\Delta\hat{s}_{znr}$$

$$= \sum_{n=1}^{N}\sum_{r<n} \left(\frac{\hat{X}_n^1 - \hat{X}_r^1}{\hat{X}^0}\right)\Delta\hat{s}_{znr}$$

This expression tells us that the total reallocation effect can be broken down into effects related to reallocations between each pair of sectors. For each pair, the contribution is determined by the direction of the reallocation and the difference between the productivity levels of each sector as a percentage of the initial aggregate MFP level. Reallocations from a sector with lower productivity to one with higher productivity will always have a positive effect on total productivity. This contribution can be divided among the two sectors, but the choice of how to do so is inherently arbitrary. These pairwise contributions can be broken down into level and growth effects as we are accustomed to:

$$\sum_{n=1}^{N}\sum_{r<n} \left(\frac{\hat{X}_n^0 - \hat{X}_r^0}{\hat{X}^0}\right)\Delta\hat{s}_{znr} + \left(\frac{\widehat{(X}_n^1 - \hat{X}_n^0) - (\hat{X}_r^1 - \hat{X}_r^0)}{\hat{X}^0}\right)\Delta\hat{s}_{znr}$$

In practice, the above pairwise decomposition will often not be feasible as it requires detailed information on inter-sector resource flows. If these data are lacking, one could still use this decomposition of the reallocation effects by making an assumption regarding the nature of the inter-sector flows.

For example, a natural choice may be to assume that the contribution of a sector with a declining share of total input use to that of a sector with a rising share of total input use is proportional to the share of the declining sector in the total decline of input shares in all sectors with declining input shares. What does this mean? Suppose there are four sectors, A, B, C, and D. The employment shares of the four sectors change by -1, +2,+3, and -4 percentage points respectively. The sum of the declines is 5 percentage points, which is exactly equal to the sum of the increases. Sector A accounts for 20 per cent of the sum of the declines and sector D for 80 per cent. We would assume that sector A accounts for 20 per cent of the increase in sector B and 20 per cent of the increase in sector C. Similarly, sector B would be assumed to account for 80 per cent of the increase in sector B and 80 per cent of the increase in sector C. So the relative importance of the sectors of net inflow are assumed to be identical in all sectors with net inflows and they are proportional to the importance of each sector in total net outflows.[34]

This assumption is consistent with idea notion that inputs which leave a sector are placed in a common pool which is then drawn upon by the other industries randomly. We do not use this approach in this paper, but we think it is worth mentioning as an alternative approach to dividing the total reallocation effect among sectors which avoids the criticisms of the approaches commonly used in the literature.

B. Decomposing MFP Growth into Contributions from Labour and Capital

i. Theory

In principle, the decompositions discussed above can be extended in order to decompose growth in multifactor productivity into contributions from each input at the sector level. In particular, we will consider how one may assign contributions to changing partial productivity levels in each sector and the reallocation of each factor across sectors.

The core difficulty with decomposing aggregate multifactor productivity growth by input is that this requires some assumption regarding the relative importance of each input to total output. This is problematic in that we only observe total output, not output from labour, output from capital, etc. The approach which we will take is to associate output with an input in proportion to that input's share in total compensation.[35]

In the context of a standard growth accounting framework with a production function of the form $Y = Af(Z_1, \dots, Z_M)$, one can write:

$$\ln\left(\frac{Y^1}{Y^0}\right) = \ln\left(\frac{A^1}{A^0}\right) + \sum_{m=1}^{M} \bar{s}_{zm} \ln\left(\frac{Z_m^1}{Z_m^0}\right)$$

[34] Baldwin and Willox (2016) implement labour productivity growth decompositions that are very close to the one outlined here. In their main decomposition, they assume that an increase in an industry's labour share is drawn from other all industries in proportion to those industries' initial labour shares. In an alternative decomposition presented in an appendix, they assume that an increase in an industry's labour share is drawn from the set of industries that experienced declining labour shares in proportion to their initial labour shares. It turns out that their main decomposition produces results very similar to those of the conventional CSLS decomposition.

[35] This is effectively assuming that the average product of an input is equal to its marginal product of an input (assumed equal to the price of the input).

$$\ln\left(\frac{A^1}{A^0}\right) = \sum_{m=1}^{M} \bar{s}_{zm}\left(\ln\left(\frac{Y^1}{Y^0}\right) - \ln\left(\frac{Z_m^1}{Z_m^0}\right)\right)$$

$$\ln\left(\frac{A^1}{A^0}\right) = \sum_{m=1}^{M} \bar{s}_{zm}\left(\ln\left(\frac{Y^1}{Z_m^1}\right) - \ln\left(\frac{Y^0}{Z_m^0}\right)\right)$$

where A is the level of multifactor productivity (a Solow residual) and $\bar{s}_{zm}$ is the average (nominal) compensation share of input m.[36] As long as the growth factors are sufficiently small, this expression tells us that the growth rate of MFP is approximately equal to the weighted averages of the growth rates of the partial productivities of all the inputs, where the weights are based upon the average compensation shares of each input. In a value added framework with only labour and capital as inputs, capital compensation is calculated as a residual after labour compensation has been deducted from value added.

The above expression provides a decomposition of aggregate MFP growth into contributions from growth in aggregate labour and aggregate capital. Since we have noted that the CSLS decomposition above also provides a decomposition for growth in each partial productivity, one option would be to simply substitute these CSLS decompositions for each input into the above to obtain:

$$\hat{\gamma} \approx \sum_{m=1}^{M} \bar{s}_{zm} \sum_{n=1}^{N} \left[\hat{s}_{Yn}^0 \hat{\gamma}_{nm} + \left(\frac{\hat{X}_{nm}^0 - \hat{X}_m^0}{\hat{X}_m^0}\right)(\hat{s}_{znm}^1 - \hat{s}_{znm}^0) + \left(\frac{(\hat{X}_{nm}^1 - \hat{X}_{nm}^0) - (\hat{X}_m^1 - \hat{X}_m^0)}{\hat{X}_m^0}\right)(\hat{s}_{znm}^1 - \hat{s}_{znm}^0)\right] \tag{4}$$

where $\hat{\gamma}_{nm}$ is the partial productivity growth rate of input m in sector n, $\hat{X}_{nm}^t$ is the partial productivity of input m in sector n at time t, and $\hat{s}_{znm}^t$ is sector n's share of input m at time t.

While this approach has the advantage of being very simple, it raises a few concerns.

This decomposition has an unappealing feature in that the sum of the within-sector partial productivity effects will diverge from the within-sector multifactor productivity effects of the CSLS and GEAD decompositions described earlier. This is because the economy-wide input shares used in this decomposition are applied to all sectors while we know that the input shares within each sector vary considerably.

To try to avoid this problem, we could alternatively take the CSLS decomposition of MFP by industry from above and try to break its within-sector and reallocation effects into contributions from capital and labour. In particular, equation (3), which was:

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[36] For simplicity, the reader can think of the above expression as being derived by taking the natural log of a Cobb-Douglas production function, although the growth accounting framework applies more generally (see Solow, 1957).

$$\hat{\gamma}_{TFP} = \sum_{n=1}^{N} \hat{s}_{Yn}^{0} \hat{\gamma}_{TFP,n} + \left(\frac{\hat{X}_n^0 - \hat{X}^0}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0) + \left(\frac{(\hat{X}_n^1 - \hat{X}_n^0) - (\hat{X}^1 - \hat{X}^0)}{\hat{X}^0}\right)(\hat{s}_{zn}^1 - \hat{s}_{zn}^0)$$

can be rewritten as:

$$\begin{aligned}\hat{\gamma}_{TFP} = \sum_{n=1}^{N} \Bigg[\sum_{m=1}^{M} \bar{\alpha}_{nm} \hat{s}_{Yn}^{0} \hat{\gamma}_{TFP,nm} + \sum_{m=1}^{M} \left(\frac{\hat{X}_n^0 - \hat{X}^0}{\hat{X}^0}\right)(\hat{s}_{znm}^1 - \hat{s}_{znm}^0) \\ + \sum_{m=1}^{M} \left(\frac{(\hat{X}_n^1 - \hat{X}_n^0) - (\hat{X}^1 - \hat{X}^0)}{\hat{X}^0}\right)(\hat{s}_{znm}^1 - \hat{s}_{znm}^0) \Bigg]\end{aligned} \quad (5)$$

where $\bar{\alpha}_{nm}$ is the average share of input m in the input costs of industry n and $\hat{s}_{znm}^{t}$ is the share of input m of industry n in the total aggregate input of the total economy. More formally, at time t, we define these shares as:

$$\alpha_{nm}^{t} = \frac{W_{nm}^{t} Z_{nm}^{t}}{\sum_{i=1}^{M} W_{ni}^{t} Z_{ni}^{t}}$$

and

$$\hat{s}_{znm}^{t} = \frac{Z_{nm}^{t}}{\sum_{i=1}^{N} \sum_{j=1}^{M} Z_{ij}^{t}}$$

Note that equation (5) assumes that the m real inputs are expressed in terms of a common unit so that $\hat{s}_{znm}^{t}$ is sensible. In a constant dollar Paasche or Laspeyres framework, where each input is assigned a fixed price through time, it is straightforward to calculate $\hat{s}_{znm}^{t}$. In other cases, it is not as obvious how aggregate input should be divided additive contributions from each input.

This decomposition is a bit more complicated than the previous one, but has the advantage that the within-sector effects from each type of input will (approximately) sum to the within-sector MFP effect by construction. However, the reallocation effects are still somewhat problematic. First, the reallocation effects are all based upon MFP (not input specific productivities) so it is not entirely input specific.

Second, while it is straightforward to additively decompose the total reallocation of all inputs into terms of reallocations of each input, these reallocations are all expressed as a percentage of total input costs. This complicates interpretation as the share of labour in total input costs can rise not only due to a reallocation of labour from one sector to another, but also because a sector substitutes labour for capital. It is not entirely clear how the expression could be simply modified in order to additively separate these effects.

Returning to the more general framework of Diewert's GEAD, we show how the approach can be extended to provide a general decomposition which addresses the shortcomings of the above extensions of the CSLS decomposition. The drawback is that we will not be able to adjust the reallocation effects of capital and labour input by sector to only consider the difference between the productivity of the sector and the average productivity level.

The derivation looks extremely similar to that of the GEAD. Contributions from specific inputs will be assessed by redefining subsectors from industry-province pairs to industry-province-input triplets. We will refer to these triplets as input-sectors. There are $A = n * m$ input-sectors.

Real output in input-sector a at time t is denoted Y_a^t. The real output of each input-sector will be assumed equal to the real output of the sector, Y_n^t, multiplied by the share of the input in the total input costs of the sector α_{nm}^t (defined above). That is, $Y_a^t = \alpha_a^t Y_n^t$.[37]

Aggregate output is given by $Y^t = \sum_{a=1}^{A} \frac{P_a^t Y_a^t}{P^t} = \sum_{a=1}^{A} p_a^t Y_a^t$ where p_a^t is the input-sector specific output price. It is assumed to be exactly the same as the real output price of the sector ($p_a^t = p_n^t$).

Similarly, aggregate input can be broken down into input from each input-sector as $Z^t = \sum_{a=1}^{A} \frac{W_a^t Z_a^t}{W^t} = \sum_{a=1}^{A} w_a^t Z_a^t$.

Mathematically this will proceed in the same way as the GEAD, so we will not provide as much description.

Define partial productivity of sector n with respect to input m as:

$$X_a^t = \frac{Y_n^t}{Z_a^t}$$

Then aggregate productivity at time t is:

$$X^t = \frac{Y^t}{Z^t}$$

$$X^t = \frac{\sum_{a=1}^{A} p_a^t Y_a^t}{\sum_{a=1}^{A} w_a^t Z_a^t}$$

[37] This is the central assumption underlying our extension of the GEAD to the estimation of contributions by input. It is fairly strong. While factors of production are typically assumed to receive a wage equal to their marginal contribution as the result of market mechanisms, the resulting compensation shares will not necessarily reflect the average contributions of each factor. For instance, suppose there are 10 units of output in a sector which uses two units of labour input. The first unit of labour is responsible for 3 units of output, and the second unit of labour 1 unit of output. The wage paid to labour is 1 unit of output, reflecting its marginal contribution so that the total compensation of labour is 2 units of output (20 per cent) while labour's total contribution to total output was actually 4 units (40 per cent). One way to view our assumption is that we are assuming the average contribution of each input is equal to its marginal contribution (the input's price). A weaker condition is that the average contributions of all factors are equal to their marginal contributions scaled by some factor which is identical across all inputs.

$$X^t = \frac{\sum_{a=1}^{A} p_a^t Z_a^t (\alpha_a^t Y_n^t / Z_a^t)}{\sum_{a=1}^{A} w_a^t Z_a^t}$$

$$X^t = \frac{\sum_{a=1}^{A} w_a^t (p_a^t / w_a^t) Z_a^t \alpha_a^t X_a^t}{\sum_{a=1}^{A} w_a^t Z_a^t}$$

$$X^t = \sum_{a=1}^{A} (p_a^t / w_a^t) \alpha_a^t X_a^t \, s_{Za}^t$$

where $s_{Za}^t = \frac{W_a^t Z_a^t}{\sum_{a=1}^{A} W_a^t Z_a^t}$ is the share of total input costs in input-sector a.

Just like before, this has a very simple interpretation. The aggregate productivity level is a weighted average of the partial productivity in each input-sector, adjusted for the relative prices of the output of the sector and the input, the share of the input-sector in aggregate economy input use, **and** the share of the input in the total compensation of the sector. Remember that this last term assumes that the share of the input in the total compensation of the sector reflects the relative contribution of the input in the total output of the sector.
Then productivity growth is given by

$$\frac{X^1}{X^0} = \frac{\sum_{a=1}^{A} (p_a^1 / w_a^1) \alpha_a^1 X_a^1 \, s_{Za}^1}{\sum_{a=1}^{A} (p_a^0 / w_a^0) \alpha_a^0 X_a^0 \, s_{Za}^0}$$

$$\frac{X^1}{X^0} = \frac{\sum_{a=1}^{A} (\alpha_a^1/\alpha_a^0)(p_a^1/p_a^0)(w_a^0/w_a^1)(X_a^1/X_a^0)(s_{Za}^1/s_{Za}^0)(p_a^0/w_a^0)\alpha_a^0 X_a^0 \, s_{Za}^0}{\sum_{a=1}^{A} (p_a^0 / w_a^0) \alpha_a^0 X_a^0 \, s_{Za}^0}$$

Next we note that

$$\frac{(p_a^0 / w_a^0) \alpha_a^0 X_a^0 s_{Za}^0}{\sum_{a=1}^{A} (p_a^0 / w_a^0) \alpha_a^0 X_a^0 \, s_{Za}^0}$$

$$= \frac{(p_a^0 / w_a^0) \alpha_a^0 (Y_n^0 / Z_a^0)(w_a^0 Z_a^0 / \sum_{a=1}^{A} w_a^0 Z_a^0)}{\sum_{a=1}^{A} (p_a^0 / w_a^0) \alpha_a^0 (Y_n^0 / Z_a^0)(w_a^0 Z_a^0 / \sum_{b=1}^{A} w_b^0 Z_b^0)}$$

$$= \frac{p_a^0 Y_a^0 / \sum_{a=1}^{A} w_a^0 Z_a^0}{\sum_{a=1}^{A} p_a^0 Y_a^0 / \sum_{b=1}^{A} w_b^0 Z_b^0}$$

$$= \frac{p_a^0 Y_a^0}{\sum_{a=1}^{A} p_a^0 Y_a^0}$$

$$\equiv s_{Ya}^0 \equiv s_{Ynm}^0$$

Finally,

$$\frac{X^1}{X^0} = \sum_{a=1}^{A} s_{Ya}^0 (\alpha_a^1/\alpha_a^0)(p_a^1/p_a^0)(w_a^0/w_a^1)(X_a^1/X_a^0)(s_{Za}^1/s_{Za}^0)$$

This looks almost the same as the GEAD, except now everything is in terms of input-sectors and we have added the term (α_a^1/α_a^0) which captures the effects of growth in the share of the input in the total compensation of the sector.
Note that the last term, growth in the share of the input-sector in total economy input costs can be broken down further since:

$$s_{Za}^t = \frac{w_a^t Z_a^t}{\sum_{a=1}^{A} w_a^t Z_a^t} = \frac{w_{nm}^t Z_{nm}^t}{\sum_{n=1}^{N} \sum_{m=1}^{M} w_{nm}^t Z_{nm}^t} = \frac{w_{nm}^t Z_{nm}^t}{\sum_{m=1}^{M} w_{nm}^t Z_{nm}^t} \frac{\sum_{m=1}^{M} w_{nm}^t Z_{nm}^t}{\sum_{n=1}^{N} \sum_{m=1}^{M} w_{nm}^t Z_{nm}^t} = s_{Znm}^t s_{Zn}^t$$

where s_{Znm}^t is the share of input m in industry n's total input costs and s_{Zn}^t is sector n's share of aggregate input in the economy. The first term captures substitution between inputs within the sector. The second term captures reallocation of all inputs towards the sector. This allows us to distinguish between reallocation of aggregate resources to a sector and changes in the relative intensity with which each input is used within the sector.[38]

$$\frac{X^1}{X^0} = \sum_{a=1}^{A} s_{Ya}^0 (\alpha_a^1/\alpha_a^0)(p_a^1/p_a^0)(w_a^0/w_a^1)(X_a^1/X_a^0)(s_{Znm}^1/s_{Znm}^0)(s_{Zn}^1/s_{Zn}^0)$$

$$\frac{X^1}{X^0} = \sum_{m=1}^{M} \sum_{n=1}^{N} s_{Ynm}^0 (\alpha_{nm}^1/\alpha_{nm}^0)(p_{nm}^1/p_{nm}^0)(w_{nm}^0/w_{nm}^1)(X_{nm}^1/X_{nm}^0)(s_{Znm}^1/s_{Znm}^0)(s_{Zn}^1/s_{Zn}^0)$$

This provides us with a decomposition analogous to that of Diewert (2015) but with separate additive terms for each input in each sector.

Of course, this can also be written in terms of growth rates as:

$$\gamma = \sum_{m=1}^{M} \sum_{n=1}^{N} s_{Ynm}^0 \{[1+\beta_{nm}][1+\gamma_{nm}][1+\rho_{nm}][1+\omega_{nm}][1+\varphi_{nm}][1+\sigma_n] - 1\} \qquad (6)$$

where β_{nm}, φ_{nm}, and σ_n are appropriately defined growth rates.

[38] The reader should note that if we had summed over n rather than m, we could have arrived at a different decomposition where the two terms would be the share of input m in total economy input costs and the share of industry n in the total economy costs of input m. These terms would reflect the role of substitution between inputs in the aggregate economy and the reallocation of each input across sectors, while our equation (6) reflects the role of substitution between inputs within each sector and the reallocation of total input use across sectors.

We can expand this expression and allocate the interaction terms in the same way as above. There are 63 separate terms for each sector in this case, so this becomes fairly tedious to write out.

Notice that β_{nm}, the growth rate of the compensation share of input m in the total output of sector n is identical to φ_{nm}. Growth in the compensation share of input m in sector n is relevant both because it changes the share of output in sector n which we assume to have been produced by input m and because it enters into our reallocation term. The decomposition can be rewritten as:

$$\gamma = \sum_{m=1}^{M}\sum_{n=1}^{N} s_{Ynm}^{0}\{[1+\gamma_{nm}][1+\rho_{nm}][1+\omega_{nm}][1+\sigma_{n}][1+\varphi_{nm}]^{2}-1\}$$

ii. Labour Data

Now we will consider the relative importance of changes related to capital and labour inputs in explaining MFP growth. Within each sector, MFP growth can be broken down into changes in labour productivity and capital productivity. Similarly, reallocation of aggregate input can be broken down into reallocation of each input and substitution between inputs.

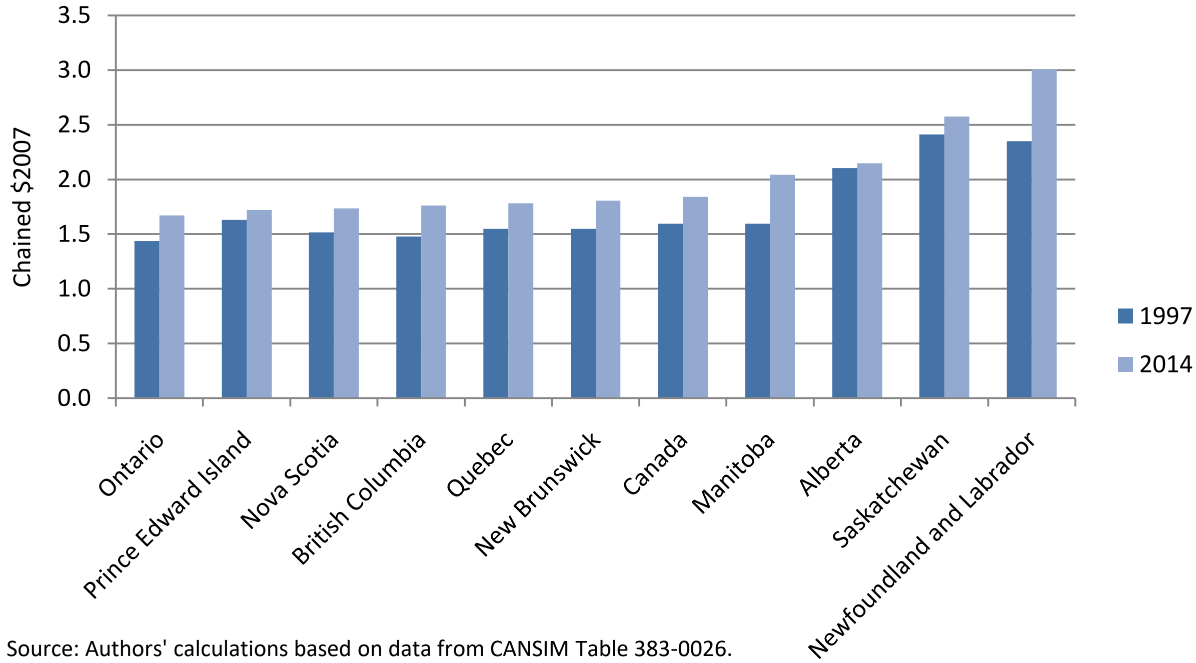
Again, it is useful to begin with an overview of trends in labour productivity, capital productivity, and the allocation of inputs across sectors before examining the results of the decomposition exercises.

Appendix Chart 1 presents labour productivity levels by province in 1997 and 2014.[39] In 2014, labour productivity was above average in the three major oil producing provinces − Newfoundland and Labrador, Saskatchewan and Alberta − and in Manitoba. All the other provinces were fairly close to the national average. The lowest level was in Ontario.

Appendix Chart 2 presents the labour productivity growth rates between 1997 and 2014 for Canada and the provinces. Alberta stands out as the province that had the lowest labour productivity growth (0.12 per cent annually), though it still had the third-highest labour productivity level at the end of the period. Labour productivity growth in most provinces was close to the average (0.85 per cent per year). Two provinces stand out as having above average labour productivity growth: Manitoba (1.47 per cent per year) and Newfoundland and Labrador (1.46 per cent per year).

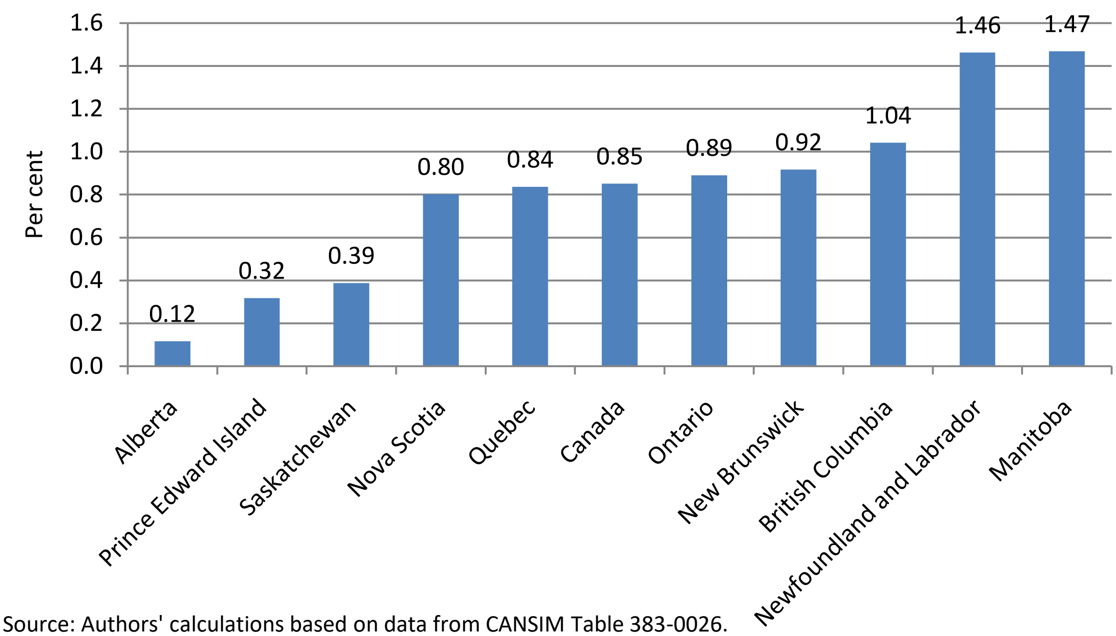
[39] Note that the concept of 'labour productivity' in this chart and in subsequent charts is real output per unit of labour input, where labour input is adjusted for labour quality and is expressed in chained 2007 dollars. This differs from the more familiar definition of labour productivity as output per hour worked. Since our aggregate and sectoral MFP estimates were constructed using quality-adjusted labour input rather than raw hours worked, it is the notion of labour productivity based on quality-adjusted labour input that is relevant for the extended decompositions discussed in this appendix.

Appendix Chart 1: Labour Productivity in Canada and the Provinces, Business Sector Industries, Chained $2007 Output per Unit of Labour Input, 1997 and 2014



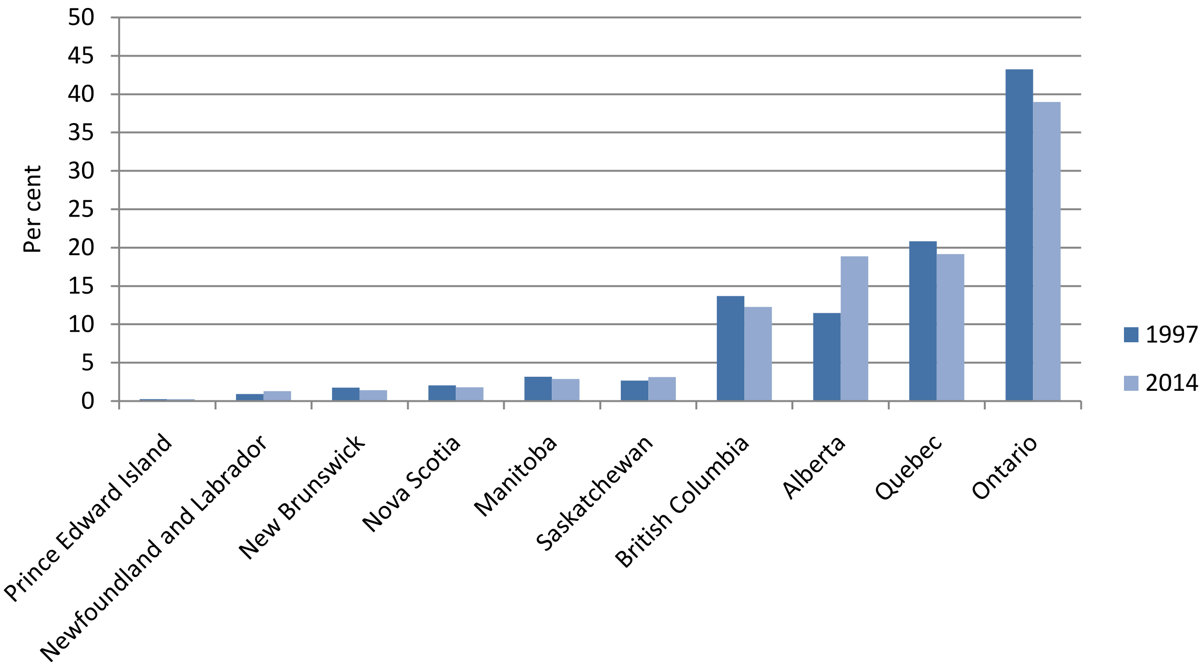
Source: Authors' calculations based on data from CANSIM Table 383-0026.

Appendix Chart 2: Labour 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.

Appendix Chart 3: Distribution of Labour Input Costs across Provinces, Business Sector Industries, Per Cent of All-Provinces Total, 1997 and 2014



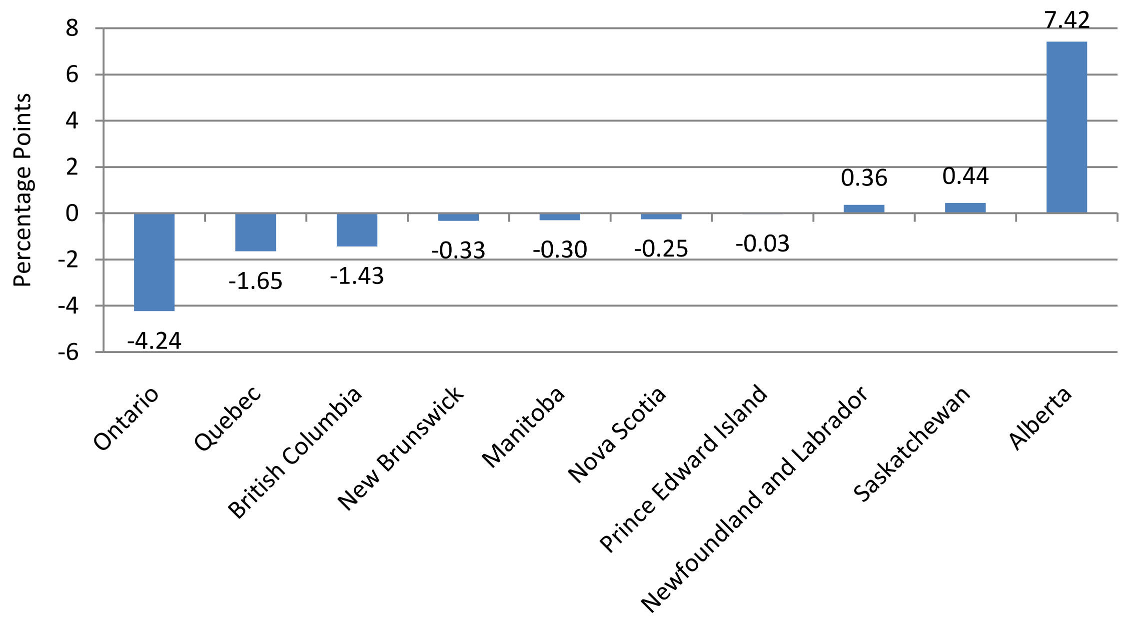
Source: Authors' calculations based on data from CANSIM Table 383-0026.

The distribution of labour input expenditures (i.e. labour compensation) across the provinces is very similar to the distribution of the total population (Appendix Chart 3). For our purposes, the reallocation of labour input across provinces between 1997 and 2014 is more relevant (Appendix Chart 4). Alberta's share of total labour input expenditures increased by 7.4 percentage points over the period, by far the largest increase among the provinces. The only other provinces to see their share of labour input costs rise over the period were Saskatchewan and Newfoundland and Labrador, the other two oil-producing provinces. Labour input shares exhibited substantial declines in Ontario (-4.2 percentage points), Quebec (-1.7 percentage points) and British Columbia (-1.4 percentage points).

Appendix Chart 5 provides labour productivity levels by industry, clarifying the sources of some of the provincial trends. The mining and oil and gas industry had by far the highest level of labour productivity in both 1997 and 2014. Though it declined significantly over the period, the industry's labour productivity (at $4.92 per unit of labour input in chained 2007 dollars) remained well above that of the second-place industry, utilities (at $3.15).

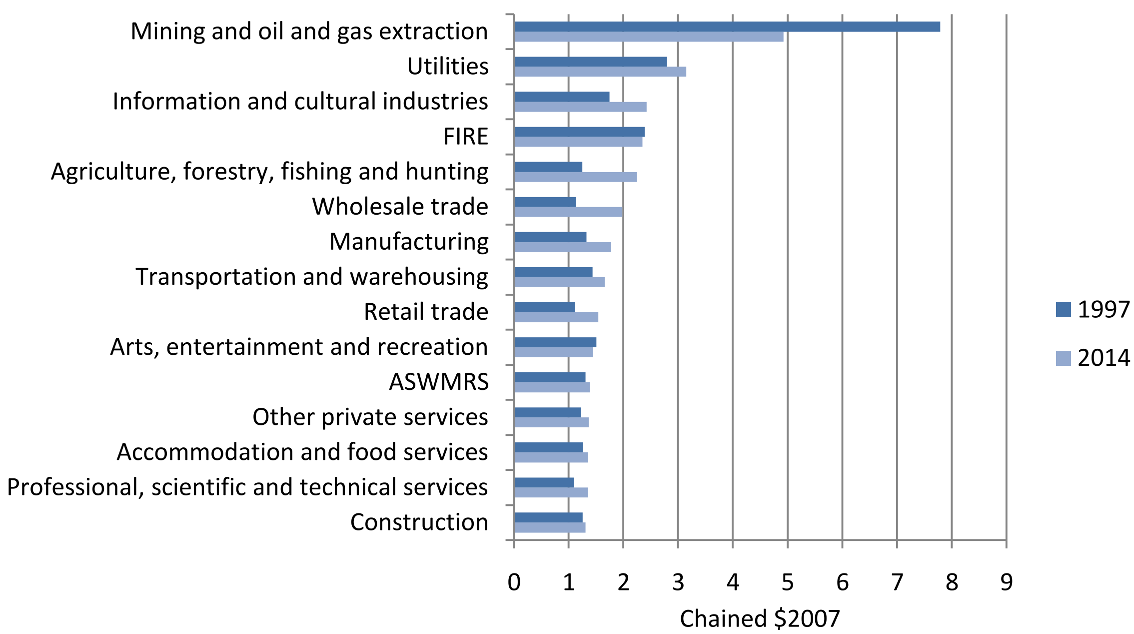
Mining and oil and gas extraction exhibited by far the largest decline in labour productivity over the 1997-2014 period, at -2.7 per cent per year. Two other industries, FIRE and arts, entertainment and recreation, registered small annual declines. The strongest labour productivity growth occurred in agriculture, forestry, hunting and fishing (3.5 per cent per year) and in wholesale trade (3.3 per cent per year). Labour productivity growth in manufacturing, at 1.7 per cent per year, was also above average.

Appendix Chart 4: Change in Provincial Shares of Labour Input Costs, Business Sector Industries, Percentage Points, 1997-2014



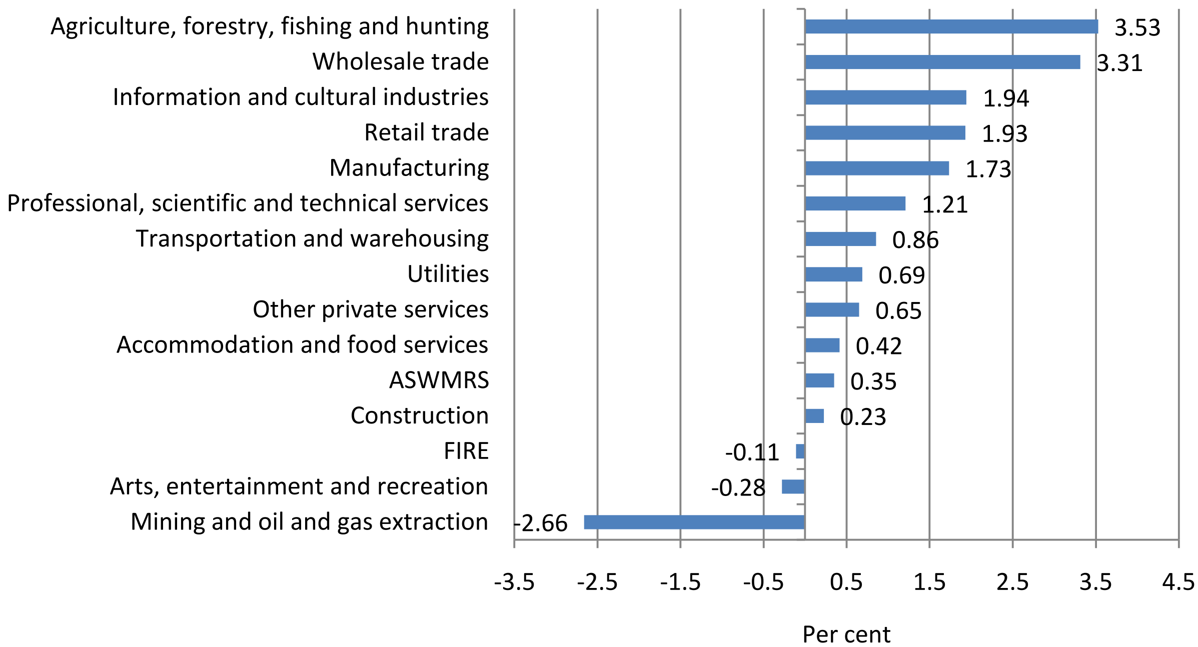
Source: Authors' calculations based on data from CANSIM Table 383-0026.

Appendix Chart 5: Labour Productivity by Business Sector Industry, All Provinces, Chained $2007 Output per Unit of Labour Input, 1997 and 2014



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

Appendix Chart 6: Labour Productivity Growth by Business Sector Industry, All Provinces, Per Cent per Year, 1997-2014

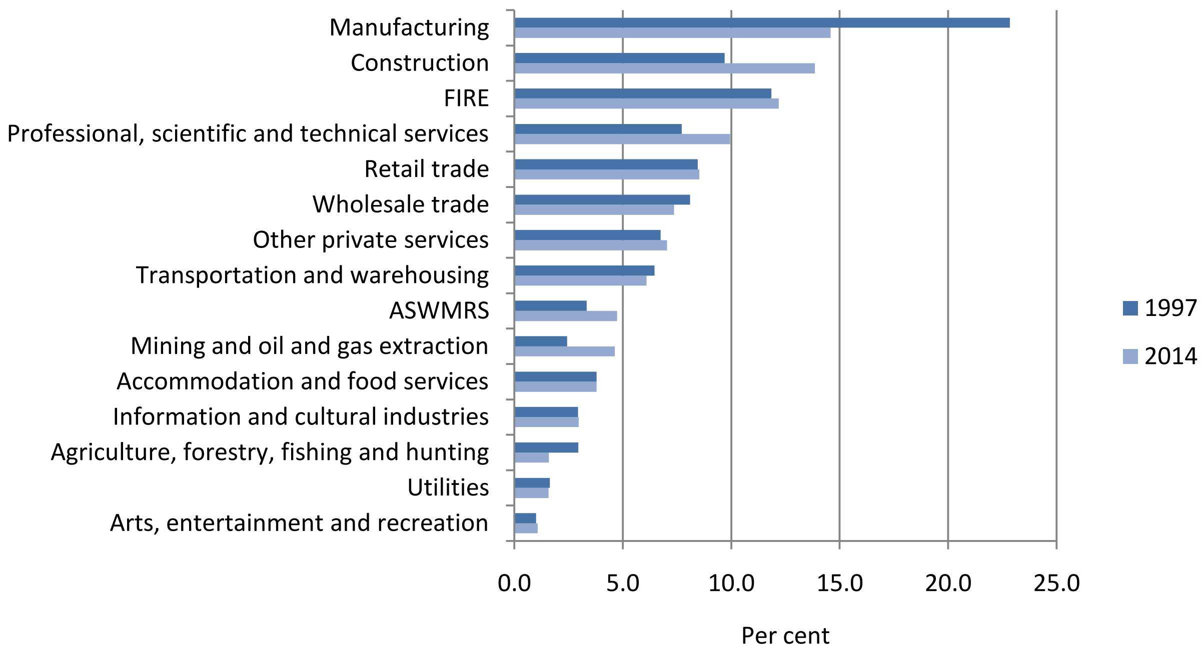


Source: Authors' calculations based on data from CANSIM Table 383-0026.

The distributions of labour input expenditures across industries in 1997 and in 2014 are depicted in Appendix Chart 7. Manufacturing had the largest labour input share in 2014 (14.6 per cent), followed by construction (13.9 per cent) and FIRE (12.2 per cent). Mining and oil and gas extraction accounted for only 4.6 per cent of aggregate labour input expenditures.

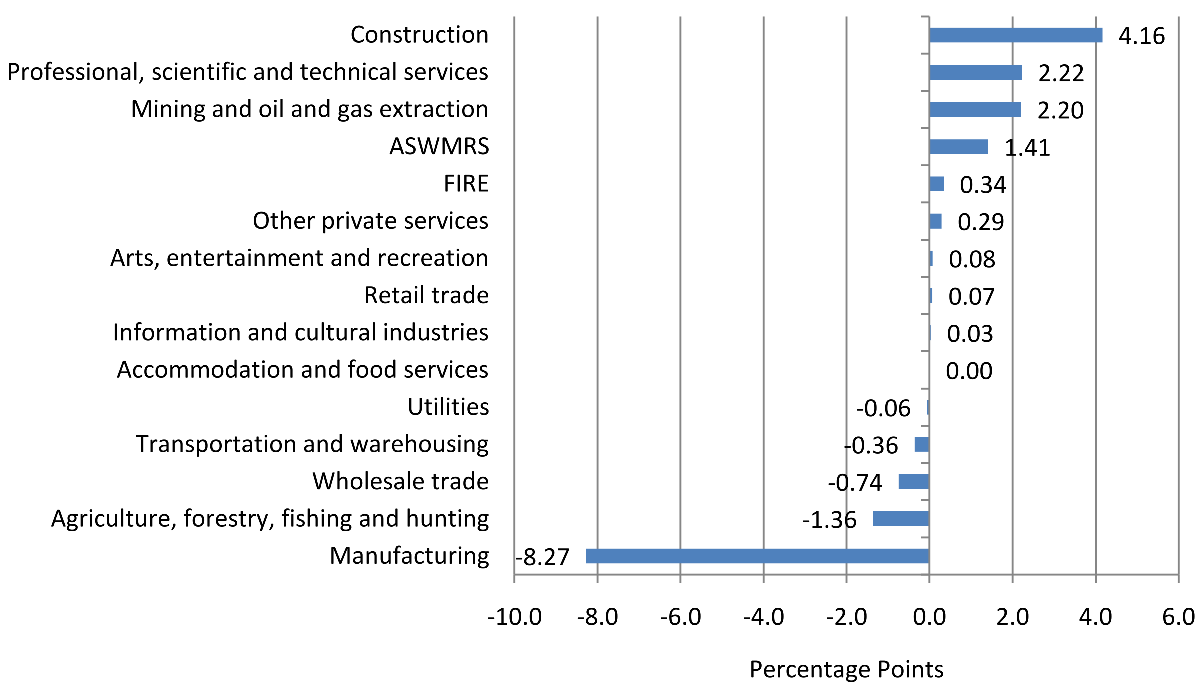
Appendix Chart 8 shows the percentage-point changes in industry shares of total labour costs between 1997 and 2014. The share of manufacturing plummeted by 8.3 percentage points over the period, by far the largest decline among the fifteen industries. The next largest decline was 1.4 percentage-points in agriculture, forestry, fishing and hunting. Construction exhibited the largest increase in labour cost share, at 4.2 percentage points, followed by professional, scientific and technical services and mining and oil and gas extraction, each at 2.2 percentage points.

Appendix Chart 7: Distribution of Labour Input Costs across Business Sector Industries, All Provinces, Per Cent of Business Sector Industries Total, 1997 and 2014



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

Appendix Chart 8: Change in Industry Shares of Labour Input Costs, All Provinces, Percentage Points, 1997-2014



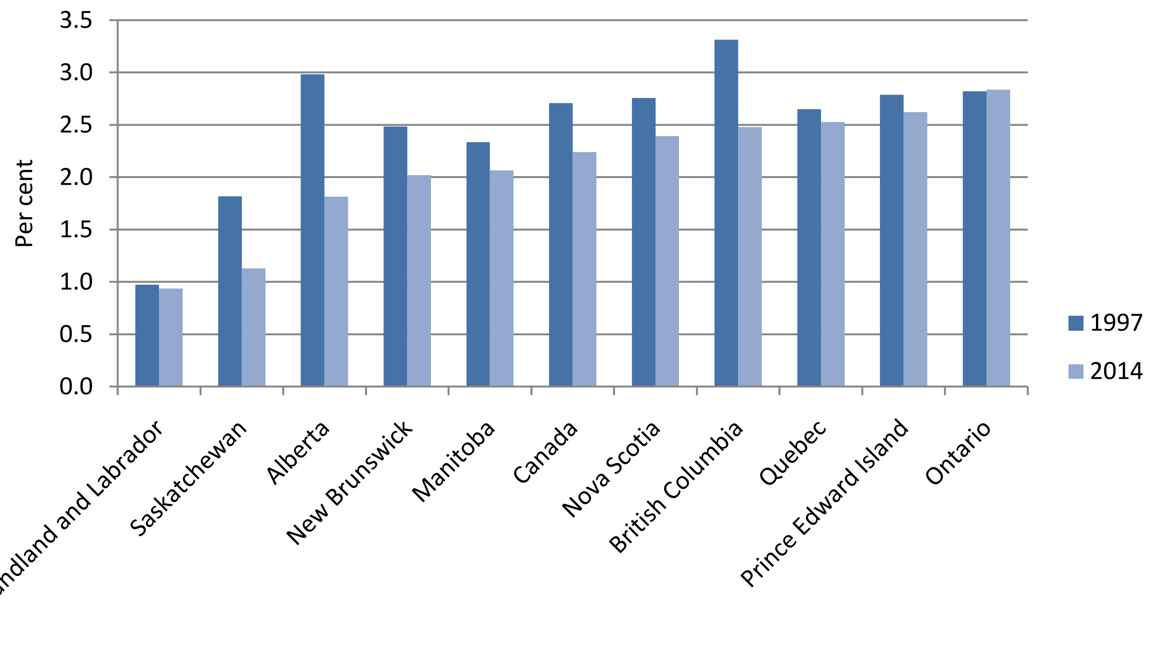
Source: Authors' calculations based on data from CANSIM Table 383-0026.

iii. Capital Data

Appendix Chart 9 displays the level of capital productivity in Canada and the provinces in 1997 and in 2014. Capital productivity is the ratio of real output to real capital services input, with both measured in chained 2007 dollars. In 2014, capital productivity was highest in Ontario, at $2.84 per unit of capital. Prince Edward Island, Quebec, British Columbia, and Nova Scotia also had capital productivity levels above the national average. Capital productivity was lowest in Newfoundland and Labrador, Saskatchewan and Alberta, the three oil producing provinces.

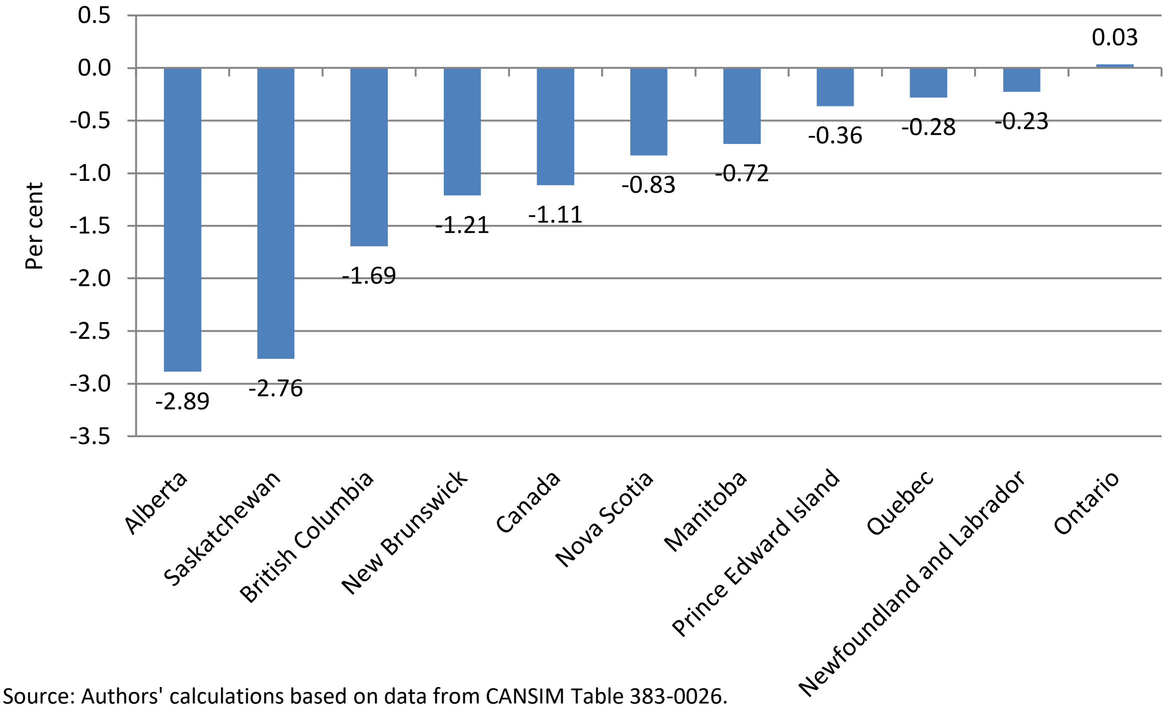
Between 1997 and 2014, capital productivity declined in every province except for Ontario, where it remained essentially unchanged (Appendix Chart 10). The largest declines were in Alberta and Saskatchewan, at -2.9 per cent per year and -2.8 per cent per year, respectively. It is likely that this is attributable to the expansion of capital-intensive mining and oil and gas extraction in those provinces. On the other hand, the decline in capital productivity in Newfoundland and Labrador was only -0.2 per cent per year. This suggests that the oil industries of Eastern and Western Canada appear to differ in terms of their capacity for capital productivity growth. Meanwhile, Ontario and Quebec − Canada's main centres of manufacturing − had capital productivity growth rates above the national average.

Appendix Chart 9: Capital Productivity in Canada and the Provinces, Business Sector Industries, Chained $2007 Output per Unit of Capital Input, 1997 and 2014



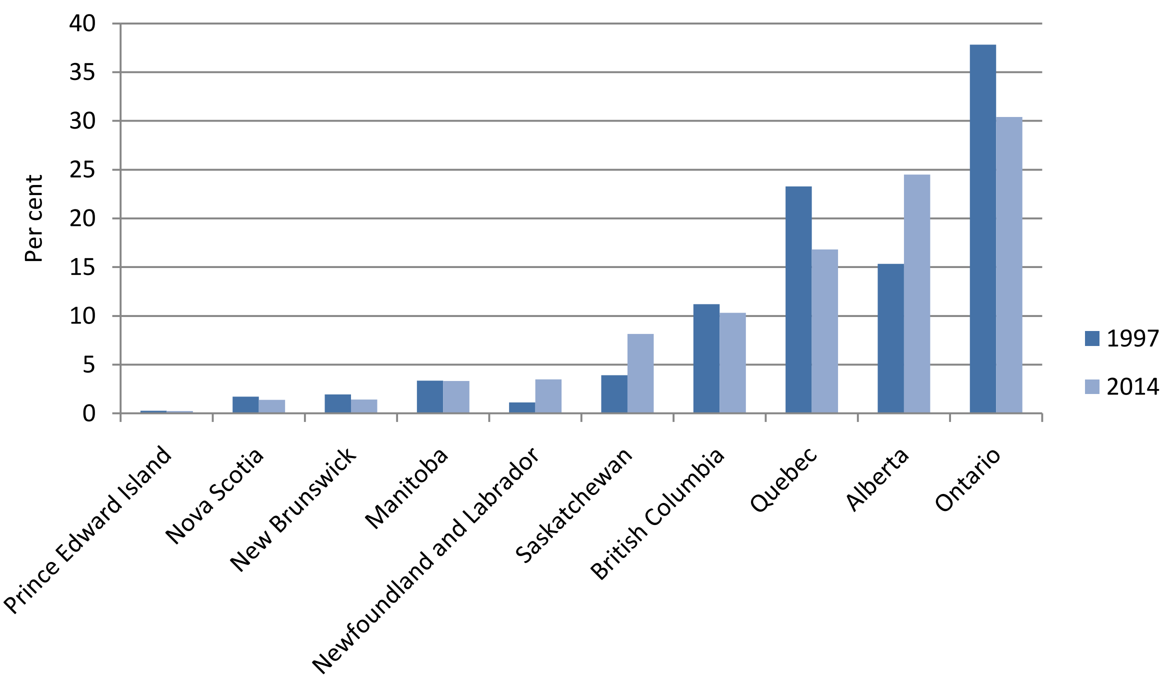
Source: Authors' calculations based on data from CANSIM Table 383-0026.

Appendix Chart 10: Capital 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.

Appendix Chart 11: Distribution of Capital Input Costs across Provinces, Business Sector Industries, Per Cent of All-Provinces Total, 1997 and 2014



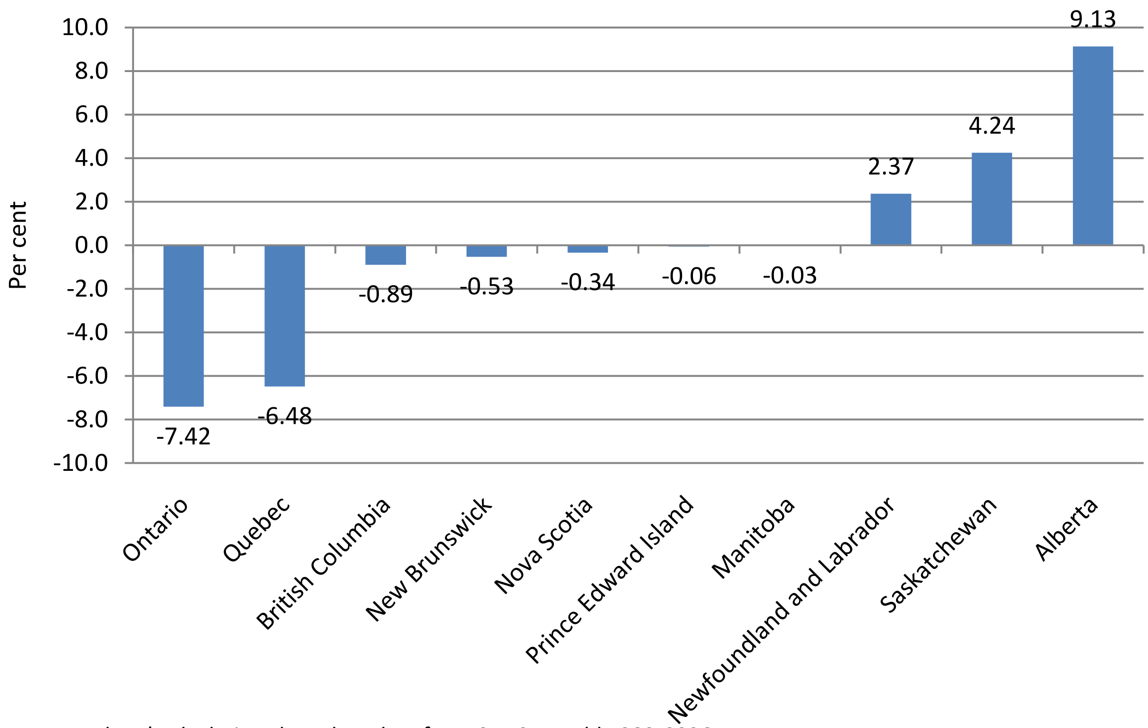
Source: Authors' calculations based on data from CANSIM Table 383-0026.

Ontario accounted for the largest share of Canada's total capital expenditures in 2014, at 30.4 per cent, followed by Alberta (24.5 per cent) and Quebec (16.8 per cent). The three Maritime provinces had the smallest shares to total capital costs; none accounted for more than 1.4 per cent of total capital.

Between 1997 and 2014 there was a significant reallocation of capital from Ontario and Quebec to Alberta, Saskatchewan and Newfoundland and Labrador (Appendix Chart 12). The shares of Ontario and Quebec declined by 7.4 percentage points and 6.5 percentage points, respectively. Alberta exhibited the largest increase in capital share, at 9.1 percentage points, followed by Saskatchewan at 4.2 percentage points and Newfoundland and Labrador at 2.4 percentage points. The three oil-producing provinces were the only provinces to gain capital share over the period.

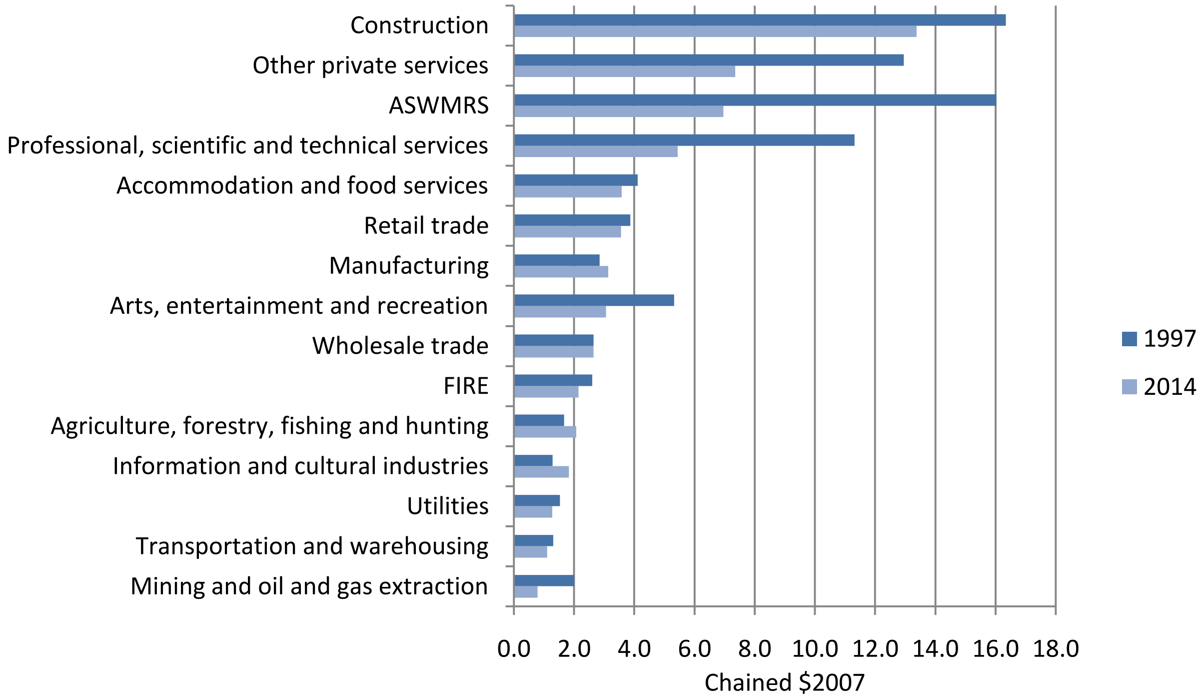
Given the low capital productivity levels in Alberta compared to Ontario and Quebec, this reallocation put downward pressure on aggregate capital productivity and on MFP (ignoring changes in relative prices).

Appendix Chart 12: Change in Provincial Shares of Capital Input Costs, Business Sector Industries, Percentage Points, 1997-2014



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

Appendix Chart 13: Capital Productivity by Business Sector Industry, All Provinces, Chained $2007 Output per Unit of Capital Input, 1997 and 2014

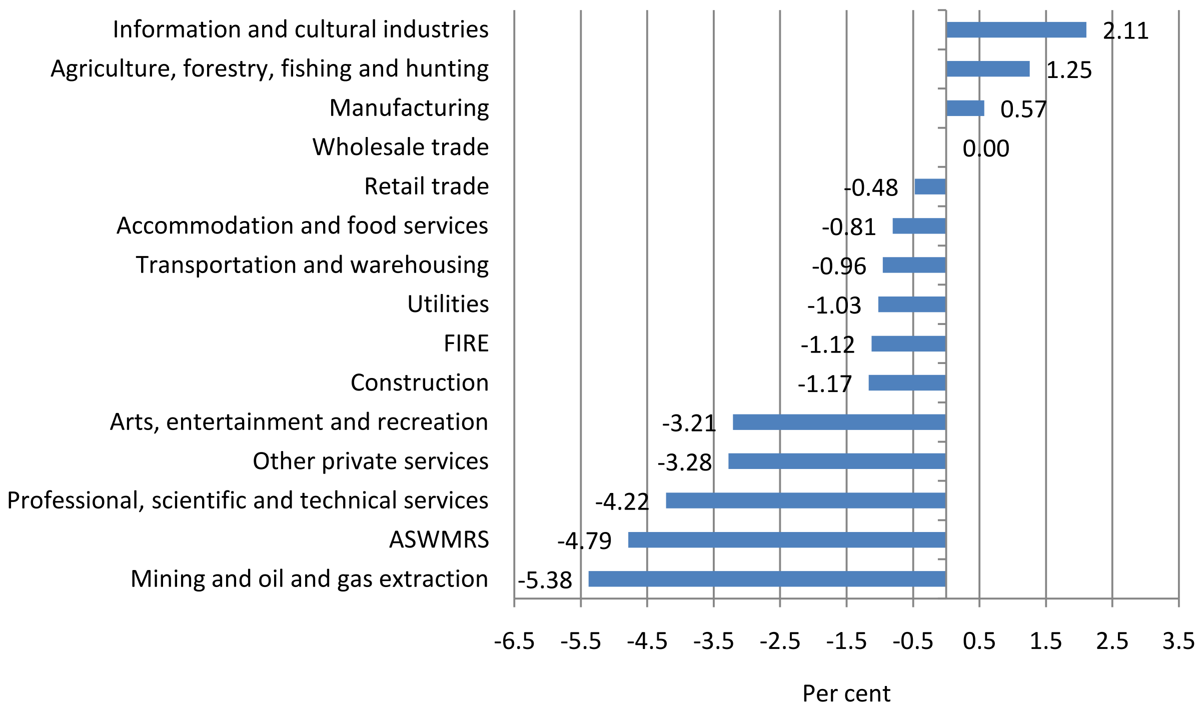


Source: Authors' calculations based on data from CANSIM Table 383-0026.

There is wide variation in capital productivity levels across industries (Appendix Chart 13). Construction had the highest level of capital productivity in 2014, at $13.38 per dollar of capital services, followed by other private services at $7.35. The lowest level of capital productivity was in mining and oil and gas extraction ($0.78), which is unsurprising given the provincial patterns depicted earlier. Capital productivity in manufacturing was in the middle of the pack, at $3.14.

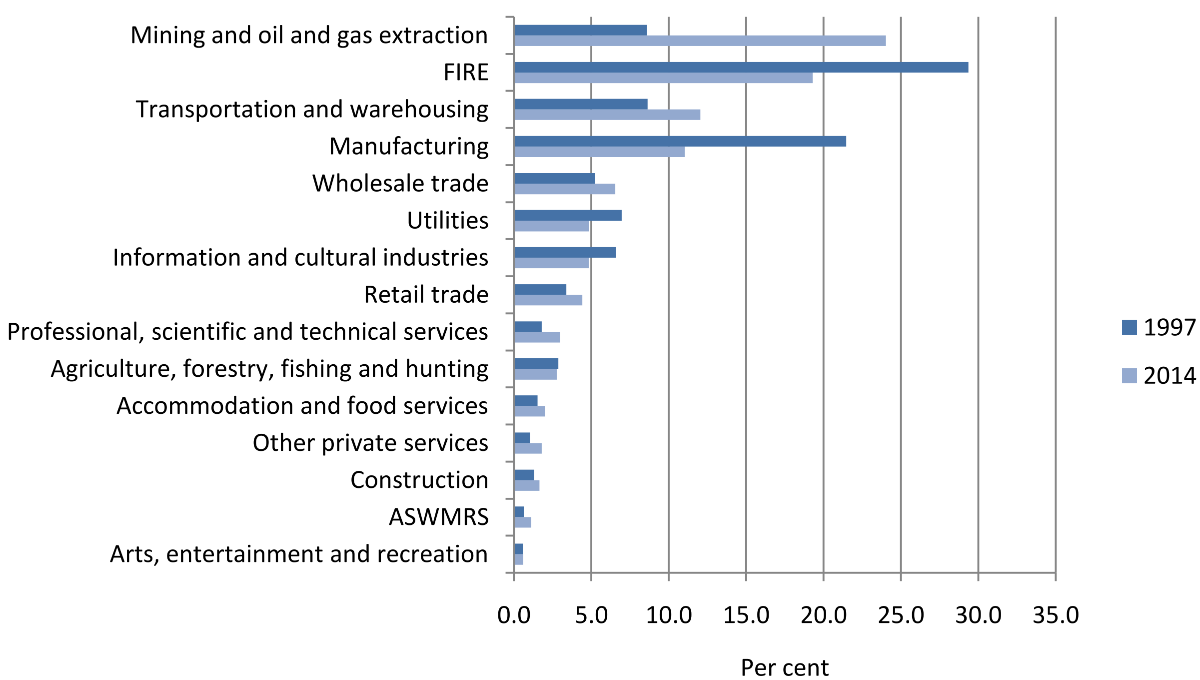
Appendix Chart 14 shows the rates of capital productivity growth by industry over the 1997-2014 period. Only three industries exhibited positive capital productivity growth over the period: information and cultural industries (2.1 per cent per year); agriculture, forestry, fishing and hunting (1.3 per cent per year); and manufacturing (0.6 per cent per year). The lowest rate of capital productivity growth over the period was -5.4 per cent per year in mining and oil and gas extraction.

Appendix Chart 14: Capital Productivity Growth by Business Sector Industry, All Provinces, Per Cent per Year, 1997-2014



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

Appendix Chart 15: Distribution of Capital Input Costs across Business Sector Industries, All Provinces, Per Cent of Business Sector Industries Total, 1997 and 2014



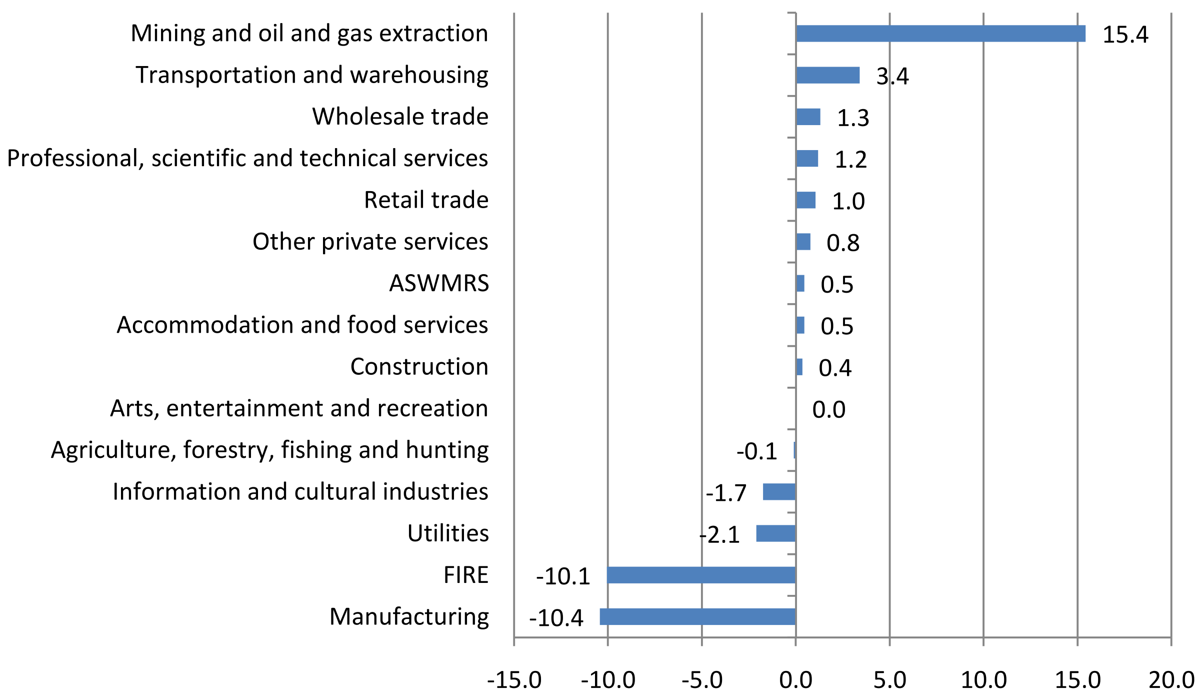
Source: Authors' calculations based on data from CANSIM Table 383-0026.

The mining and oil and gas extraction industry accounted for the largest share of total capital costs in 2014, at 24.0 per cent. It was followed by FIRE at 19.3 per cent, transportation and warehousing at 12.0 per cent, and manufacturing at 11.0 per cent. The smallest share was in arts, entertainment and recreation, at 0.6 per cent.

Between 1997 and 2016, there was a significant reallocation of capital away from manufacturing and FIRE and into mining and oil and gas extraction (Appendix Chart 16). The capital share of mining and oil and gas extraction increased by 15.4 percentage points over the period, while the shares of manufacturing and FIRE fell by 10.4 and 10.1 percentage points, respectively. These were by far the largest industry-level changes over the period. The provincial changes depicted in Appendix Chart 12 are clearly driven by these industry-level changes.

The reallocation from manufacturing and FIRE to mining and oil and gas extraction will have significantly lowered capital productivity and MFP, as mining and oil and gas extraction had far lower capital productivity.

Appendix Chart 16: Change in Industry Shares of Capital Input Costs, All Provinces, Percentage Points, 1997-2014



iv. Results

We implement two different decompositions of MFP by industry, province, and input. As was the case with our baseline GEAD and CSLS decompositions by industry and province, we end up with two very different stories.

First, we present the results of the GEAD decomposition in Appendix Table 1. For convenience, the definitions of the contributions are summarized in the following table:

γ	Contribution of growth in the productivity of the input within the sector
ρ	Contribution of growth in sector's relative output price
ω	Contribution of growth in sector's relative (inverse) input price
σ	Contribution of growth in sector's share of total input costs
φ	Contribution of growth in an input's share of total input costs within the industry

Aggregate MFP growth was 0.28 per cent over the 1997-2014 period. According to the GEAD, within-sector productivity growth made a negative contribution of -0.03 percentage points to this total, while inverse input price growth made a further negative contribution of -3.50 percentage points. These were offset by positive contributions from relative output price growth (2.05 percentage points), sectoral input share growth (1.56 percentage points) and input reallocation within sectors (0.20 percentage points).

The breakdown of these total effects into contributions by input reveals that capital and labour made offsetting contributions to aggregate MFP growth. Within-sector labour productivity growth contributed 10.44 percentage points to total MFP growth, but this was completely offset by a contribution of -10.46 percentage points from capital productivity growth. The relative output price and relative input price effects made negative contributions via labour and positive contributions via capital. This presumably reflects rising relative output prices in capital-intensive sectors and the reverse in relatively labour-intensive sectors, as well as falling prices of capital relative to labour generally. The reallocation of total input costs across sectors made a negative contribution via labour and positive contributions via capital. This indicates that sectors that had relatively high labour shares in 1997 subsequently saw their shares of total input expenditures decline (on average), while those that were relatively capital intensive in 1997 saw their input cost shares rise in subsequent years (on average). The reallocation of input costs across inputs within sectors also contributed negatively via labour and positively via capital; capital shares of total input costs within sectors were generally rising over the period.

As in the baseline GEAD results presented in the main text of this report, the extended GEAD results in Appendix Table 1 indicate that Alberta and Saskatchewan made large positive contributions to total MFP growth while Ontario and Quebec made substantial negative contributions. Alberta and Saskatchewan saw positive contributions from both capital and labour, while Ontario and Quebec saw negative contributions from both inputs. In all four provinces, the key drivers were the relative output price and sectoral input share effects.

Among industries, the largest positive contribution to aggregate MFP growth came from mining and oil and gas extraction (5.88 percentage points). The largest negative contribution

Appendix Table 1: Decomposition of MFP Growth by Input, Province and Business Sector Industry, Extended GEAD, Percentage Point Contributions, 1997-2014

	Labour						Capital						Total					
	γ	ρ	ω	σ	ϕ	TE	γ	ρ	ω	σ	ϕ	TE	γ	ρ	ω	σ	ϕ	TE
Total	10.44	-1.13	-6.68	-0.36	-2.45	-0.19	-10.46	3.18	3.18	1.92	2.66	0.47	-0.03	2.05	-3.50	1.56	0.20	0.28
Alberta	1.30	2.04	-3.43	4.73	-0.24	4.41	-5.58	3.34	0.90	4.34	0.23	3.22	-4.28	5.38	-2.53	9.08	-0.01	7.64
British Columbia	1.55	-0.47	-0.53	-0.85	-0.61	-0.91	-1.47	-0.17	1.20	-0.51	0.62	-0.34	0.08	-0.65	0.67	-1.36	0.01	-1.25
Manitoba	0.49	-0.02	-0.23	-0.07	-0.33	-0.15	-0.24	0.07	-0.02	-0.05	0.33	0.09	0.26	0.05	-0.25	-0.11	0.00	-0.06
New Brunswick	0.17	-0.06	-0.03	-0.19	-0.07	-0.19	-0.21	-0.06	0.22	-0.20	0.08	-0.17	-0.04	-0.12	0.19	-0.39	0.01	-0.35
Newfoundland and Labrador	0.24	0.20	-0.27	0.37	-0.31	0.23	0.53	0.91	-2.25	1.21	0.40	0.80	0.77	1.11	-2.52	1.58	0.09	1.03
Nova Scotia	0.19	-0.04	-0.11	-0.13	-0.12	-0.21	-0.16	-0.07	0.17	-0.18	0.13	-0.12	0.02	-0.11	0.06	-0.31	0.01	-0.32
Ontario	4.10	-2.40	-0.81	-3.35	-0.31	-2.77	-0.22	-1.87	1.96	-2.62	0.35	-2.40	3.88	-4.27	1.15	-5.97	0.04	-5.17
Prince Edward Island	0.02	0.00	0.00	-0.01	-0.02	-0.01	-0.02	-0.01	0.02	-0.03	0.03	-0.01	0.00	-0.01	0.02	-0.05	0.01	-0.03
Quebec	1.99	-0.97	-0.80	-1.62	0.49	-0.89	-0.77	-1.19	2.17	-2.00	-0.49	-2.28	1.23	-2.16	1.38	-3.62	0.01	-3.17
Saskatchewan	0.37	0.59	-0.48	0.75	-0.93	0.30	-2.32	2.23	-1.18	1.96	0.98	1.67	-1.95	2.82	-1.66	2.71	0.04	1.97
Accommodation and food services	0.15	0.03	-0.22	0.11	-0.38	-0.31	-0.10	0.01	-0.18	0.04	0.39	0.16	0.05	0.04	-0.40	0.15	0.01	-0.15
ASWMRS	0.18	0.36	-0.43	0.98	-0.21	0.89	-0.43	0.06	0.22	0.17	0.24	0.26	-0.25	0.42	-0.20	1.15	0.03	1.15
Agriculture, forestry, fishing and hunting	0.84	-0.19	-0.05	-0.52	-0.78	-0.70	0.29	-0.07	-0.44	-0.36	0.77	0.19	1.13	-0.26	-0.49	-0.88	-0.01	-0.51
Arts, entertainment and recreation	-0.03	0.06	-0.05	0.03	-0.02	-0.01	-0.16	0.03	0.10	0.01	0.03	0.01	-0.19	0.09	0.06	0.04	0.01	0.01
Construction	0.28	1.72	-0.95	2.70	0.06	3.81	-0.15	0.16	0.11	0.26	-0.06	0.32	0.14	1.87	-0.84	2.96	0.00	4.13
FIRE	-0.07	-0.73	-0.40	-1.49	2.88	0.19	-2.13	-1.09	5.18	-2.29	-2.96	-3.30	-2.20	-1.82	4.77	-3.77	-0.09	-3.11
Information and cultural industries	0.58	-0.56	-0.08	-0.27	0.44	0.10	0.84	-0.74	0.35	-0.36	-0.45	-0.34	1.43	-1.30	0.27	-0.63	-0.01	-0.24
Manufacturing	3.30	-2.55	-1.05	-6.23	1.42	-5.11	0.72	-1.35	1.61	-3.38	-1.46	-3.85	4.01	-3.89	0.56	-9.61	-0.03	-8.96
Mining and oil and gas extraction	-1.15	2.03	-0.72	2.10	-1.49	0.77	-7.05	7.16	-4.03	7.35	1.68	5.10	-8.20	9.19	-4.75	9.45	0.19	5.88
Other private services	0.52	0.45	-0.44	0.37	-0.69	0.20	-0.42	0.06	-0.02	0.06	0.74	0.42	0.10	0.51	-0.46	0.43	0.04	0.62
Professional, scientific and technical services	1.16	0.42	-0.74	1.46	-0.61	1.69	-0.86	0.08	0.49	0.28	0.66	0.66	0.29	0.50	-0.24	1.75	0.06	2.35
Retail trade	1.59	-0.74	-0.43	0.26	-0.82	-0.15	-0.10	-0.23	-0.07	0.10	0.82	0.51	1.49	-0.98	-0.51	0.36	0.00	0.37
Transportation and warehousing	0.40	-0.27	-0.08	0.35	-1.27	-0.88	-0.46	-0.25	-0.64	0.54	1.28	0.47	-0.06	-0.52	-0.72	0.89	0.00	-0.41
Utilities	0.11	-0.03	-0.29	-0.23	0.32	-0.13	-0.44	-0.09	0.57	-0.58	-0.31	-0.85	-0.33	-0.12	0.28	-0.81	0.01	-0.98
Wholesale trade	2.59	-1.12	-0.75	0.02	-1.30	-0.56	-0.01	-0.56	-0.08	0.06	1.29	0.71	2.58	-1.68	-0.83	0.08	0.00	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.
γ = Within-sector partial productivity growth. ρ = Relative output price growth. ω = Inverse relative input price growth. σ = Growth of sector's share of aggregate input costs. ϕ = Growth of input's share of sectoral input costs.
TE = Total effect.

was from manufacturing (-8.96 percentage points). Again, these findings are consistent with the baseline results. Mining and oil and gas extraction made positive contributions through both labour and capital, while manufacturing made negative contributions through both inputs. For both sectors and both inputs, the within-sector effects and the total contributions had opposite signs. Manufacturing had positive within-sector contributions from both labour productivity growth and capital productivity growth, while mining and oil and gas extraction made negative contributions via the within-sector effects for both inputs. These effects were swamped by the relative output price and sectoral input share effects.

The results of the extended CSLS decomposition are presented in Appendix Table 2.[40] As in the baseline results presented in the main text, the CSLS decomposition provides results that are very different from those of the GEAD.

According to the CSLS decomposition, within-sector productivity growth contributed 2.28 percentage points to aggregate MFP growth over the 1997-2014 period. The reallocation level effect and the reallocation growth effect made large offsetting contributions of 11.32 percentage points and -12.76 percentage points, respectively, as resources were reallocated into sectors with above average productivity levels and below average productivity growth rates.

Labour productivity growth made a large positive contribution of 8.76 percentage points to aggregate MFP growth while capital productivity growth made a substantial negative contribution of -7.91 percentage points. These effects were driven almost entirely by within-sector productivity growth. The reallocation level and growth effects for labour productivity were almost exactly offsetting, while capital reallocation made a net negative contribution of -1.47 percentage points.

Alberta made the largest negative contribution to aggregate MFP growth among the provinces, at -3.47 percentage points, while Ontario made the largest positive contribution at 2.88 percentage points. Both provinces made positive contributions via labour productivity but negative contributions via capital productivity.

Among the industries, the largest positive contribution was from manufacturing (3.63 percentage points) while the largest negative contribution was from mining and oil and gas extraction (-6.90 percentage points). Manufacturing saw a positive contribution from labour productivity and a negative contribution from capital productivity, while both inputs contributed negatively in mining and oil and gas extraction.

As in the baseline results, the key difference between the extended GEAD and the extended CSLS decomposition is that the former includes relative price effects and the latter excludes them. Sector contributions under the CSLS decomposition are driven mainly by within-sector productivity growth, while in the GEAD within-sector productivity growth is swamped by the impact of relative price changes.

[40] The total effect in Appendix Table 2 is 0.84 per cent, which differs slightly from the actual estimate of aggregate MFP growth of 0.28 per cent. As discussed in the main text, this small discrepancy arises from the non-additivity of the CSLS decomposition.

Appendix Table 2: Decomposition of MFP Growth by Input, Province and Business Sector Industry, Extended CSLS Decomposition, Percentage Point Contributions, 1997-2014

	Labour				Capital				Total			
	WSE	RLE	RGE	TE	WSE	RLE	RGE	TE	WSE	RLE	RGE	TE
Total	8.72	4.75	-4.71	8.76	-6.44	6.57	-8.05	-7.91	2.28	11.32	-12.76	0.84
Alberta	-0.40	3.57	-2.73	0.44	-3.34	2.16	-2.74	-3.91	-3.74	5.74	-5.47	-3.47
British Columbia	1.50	0.22	-0.19	1.52	-1.20	0.73	-0.95	-1.42	0.30	0.95	-1.14	0.10
Manitoba	0.53	0.03	-0.07	0.49	-0.19	0.13	-0.10	-0.15	0.35	0.16	-0.17	0.33
New Brunswick	0.21	-0.03	-0.04	0.14	-0.14	0.08	-0.06	-0.13	0.07	0.04	-0.10	0.01
Newfoundland and Labrador	0.30	0.10	0.03	0.42	0.11	-0.03	-0.05	0.03	0.40	0.07	-0.03	0.45
Nova Scotia	0.21	0.01	-0.05	0.17	-0.15	0.20	-0.15	-0.10	0.06	0.21	-0.20	0.06
Ontario	4.10	0.52	-0.93	3.69	-0.27	2.04	-2.58	-0.81	3.84	2.56	-3.51	2.88
Prince Edward Island	0.01	0.00	0.00	0.01	-0.01	0.03	-0.03	0.00	0.01	0.03	-0.03	0.01
Quebec	2.14	-0.13	-0.29	1.71	-0.74	1.06	-0.79	-0.48	1.40	0.92	-1.09	1.24
Saskatchewan	0.13	0.46	-0.42	0.17	-0.52	0.17	-0.59	-0.94	-0.39	0.63	-1.02	-0.77
Accommodation and food services	0.13	0.01	-0.01	0.13	-0.16	0.03	-0.07	-0.20	-0.03	0.04	-0.08	-0.07
ASWMRS	0.11	-0.13	-0.08	-0.10	-0.62	1.62	-1.19	-0.18	-0.51	1.50	-1.26	-0.28
Agriculture, forestry, fishing and hunting	1.02	0.16	-0.33	0.85	0.33	0.18	-0.28	0.23	1.35	0.34	-0.61	1.08
Arts, entertainment and recreation	-0.02	0.00	-0.01	-0.04	-0.14	0.16	-0.16	-0.14	-0.16	0.16	-0.17	-0.18
Construction	0.15	-0.54	-0.25	-0.64	-0.48	0.90	-0.34	0.08	-0.33	0.36	-0.60	-0.56
FIRE	-0.12	0.23	-0.09	0.02	-1.24	0.24	-0.11	-1.11	-1.35	0.47	-0.20	-1.09
Information and cultural industries	0.79	0.02	-0.05	0.75	0.59	0.40	-0.34	0.65	1.38	0.41	-0.39	1.40
Manufacturing	3.60	0.87	-0.54	3.93	1.09	-0.13	-1.27	-0.31	4.69	0.74	-1.80	3.63
Mining and oil and gas extraction	-2.91	4.37	-2.59	-1.14	-3.15	-0.97	-1.65	-5.76	-6.06	3.41	-4.24	-6.90
Other private services	0.36	-0.06	-0.01	0.29	-0.92	0.90	-0.51	-0.53	-0.57	0.84	-0.52	-0.25
Professional, scientific and technical services	0.73	-0.36	-0.01	0.37	-1.16	2.55	-1.73	-0.34	-0.43	2.19	-1.74	0.02
Retail trade	1.28	-0.05	0.03	1.26	-0.17	0.08	-0.02	-0.11	1.11	0.03	0.01	1.15
Transportation and warehousing	0.52	0.01	-0.03	0.49	-0.25	0.08	-0.08	-0.25	0.26	0.09	-0.12	0.23
Utilities	0.55	0.02	-0.46	0.11	-0.22	0.40	-0.15	0.04	0.33	0.42	-0.61	0.14
Wholesale trade	2.54	0.20	-0.26	2.48	0.06	0.13	-0.16	0.03	2.60	0.32	-0.41	2.51

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.

WSE = Within-sector effect. RLE = Reallocation level effect. RGE = Reallocation growth effect. TE = Total effect.