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CENTRE FOR THE STUDY OF LIVING STANDARDS

Decomposing Multifactor Productivity Growth in Canada by Industry and Province, 1997-2012

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Abstract

Productivity growth is essential for raising living standards in the long run. Unfortunately, multifactor productivity growth has been almost non-existent in Canada over the last four decades. This paper examines the specific sources of Canada's weak multifactor productivity growth of 0.76 per cent annually between 1997 and 2012 by province and industry. Two decompositions from the literature are applied which lead to very different conclusions. A generalized exactly additive decomposition (GEAD), which includes price effects and treats any growth in a sector's input share as a positive contribution to aggregate MFP (holding prices constant) from that sector, suggests that rising natural resource prices and 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 dragged MFP growth down. In contrast, the "CSLS decomposition" excludes changes in relative prices and considers reallocation to a sector to have a positive effect on productivity only if that sector has above average productivity, finding that mining and oil and gas was the main hindrance to Canada's MFP performance while manufacturing, finance, insurance, real, estate, and leasing, and wholesale trade were the major sources of MFP growth which was concentrated in Ontario, Quebec, and BC.

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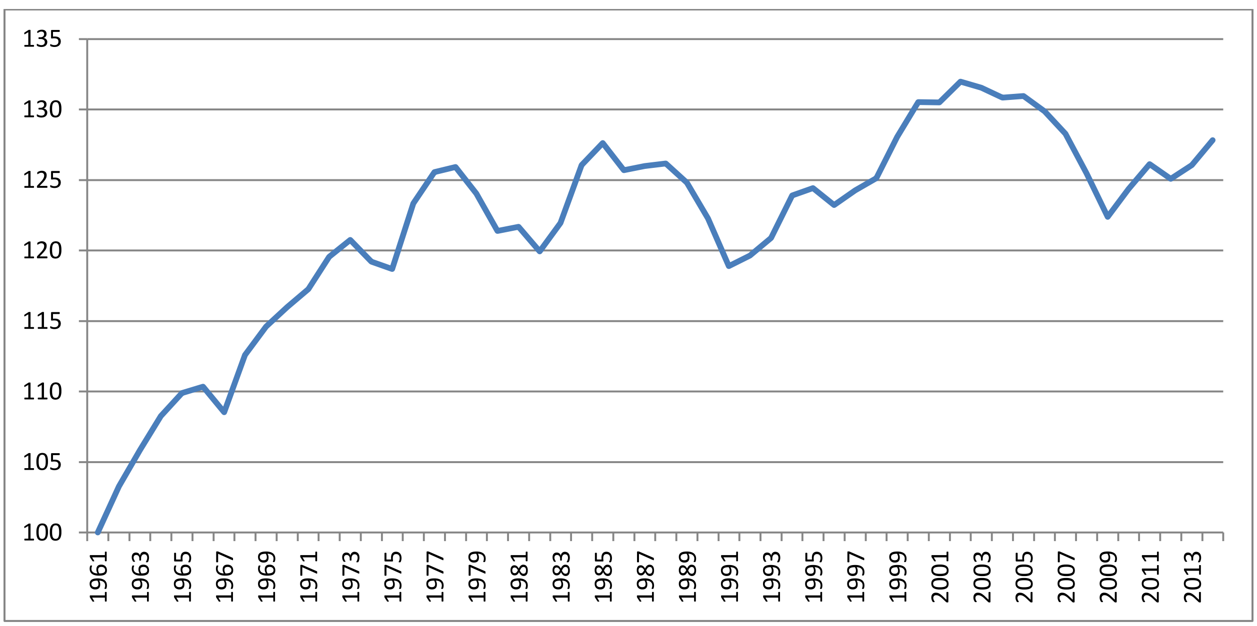
I. Introduction

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

An 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.

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



Source: CANSIM Table 383-0021

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[1] This report was written by Andrew Sharpe and Matthew Calver. Andrew is the Executive Director of the Centre for the Study of Living Standards (CSLS). Matthew is an economist at the CSLS. The authors would like to thank Alexander Murray for updates to the data. Email: andrew.sharpe@csls.ca

[2] Also commonly referred to as total factor productivity (TFP).

For the past several decades, MFP growth in Canada has been very disappointing. Chart 1 presents an index of Statistics Canada's estimates 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. During the 1960s and 1970s, MFP growth was generally quite strong. MFP rose by 26 per cent between 1961 and 1978. However, MFP in 2014 was only 1.5 per cent higher than it had been in 1978 (although it had been as high as 4.8 per cent above the 1978 level at its peak in 2002).

This productivity growth slowdown in Canada has been of major concern to policymakers for over a decade and is still not fully understood. This paper will shine new light on the modest MFP growth observed in Canada from 1997 to 2012 by quantifying the specific contributions of each province and industry to Canada's overall MFP growth rate. This will allow for an identification of which sectors of the economy have driven the limited MFP growth which has occurred and which sectors have caused growth to lag. The Centre for the Study of Living Standards (CSLS) has previously performed similar decompositions of labour productivity growth in Canada by province and industry (Sharpe 2010; Sharpe and Thomson 2010). 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.

This paper will use two different approaches from the literature in order to decompose aggregate MFP growth between 1997 and 2012 into provincial and industry contributions. The first is a Generalized Exactly Additive Decomposition (GEAD) of MFP growth developed by Diewert (2015).[3] The GEAD has been criticized by some researchers (de Avillez 2012 and Reinsdorf 2015) because it includes changes in relative prices and can assign counterintuitive contributions to MFP growth from the reallocation of resources to an industry.[4] For this reason, we will also extend the "CSLS decomposition" of labour productivity growth which addresses these concerns to provide an alternative decomposition of MFP growth. 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 extremely different conclusions regarding the sources of MFP growth in Canada.

The paper will proceed as follows. The second section will provide an overview of the decomposition methods and data used. The GEAD will be derived and its relationship to the traditional and CSLS decompositions will be discussed at length. Previously, the CSLS

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[3] Tang and Wang (2004) originally developed a GEAD for labour productivity growth. Diewert (2015) formulates a GEAD for MFP growth.

[4] In particular, assuming prices remain constant, a reallocation of resources towards a sector with the lowest productivity level in the economy is interpreted as a positive contribution to aggregate productivity growth by that sector.

decomposition has only been applied to labour productivity growth, but we extend it to MFP growth. The third section will present the results of the MFP growth decomposition exercises, which have not previously been performed using Canadian data. The fourth section will conclude. Novel extensions of both the GEAD and CSLS decompositions which 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

There exist several formulae in the literature to estimate sectoral contributions to aggregate productivity change. This section will provide an overview of the methods which will be used in this paper. We will begin by discussing the generalized exactly additive decomposition (GEAD) of multifactor productivity (MFP) growth as formulated by Diewert (2015). Next we will discuss the "traditional" decomposition of Denison (1962) which can be viewed as a special case of the GEAD. We will argue that a third decomposition, the CSLS decomposition, takes a more appropriate approach to assigning reallocation effects by sector. After presenting these three decompositions, we will discuss how they may be extended to provide a breakdown of contributions to MFP growth associated with each input. The section closes with a discussion of the data which we will use to apply the CSLS and GEAD decompositions to Canada.

A. A Generalized Exactly Additive Decomposition (GEAD)

The GEAD was originally developed by Tang and Wang (2004) to address a problem of non-additivity of contributions in the traditional decomposition formula of Denison (1962). In particular, the contributions calculated for each sector of the economy fail to sum to the productivity growth of their aggregate when chained indexes or Fisher quantity measures are used.[5] Tang and Wang's GEAD address this problem by extending the traditional decomposition of labour productivity to take account of changes in relative prices of output. The core distinction between the GEAD and traditional approach is whether or not relative price changes are considered when assessing an industry's contribution to MFP growth. Since the traditional decomposition is a special case of the GEAD in which the effects of relative price changes are

[5] Originally, this non-additivity was not a problem because most statistical agencies produced output estimates using constant dollar Laspeyres volume measures, but it became problematic as Fisher chained volume measures increased in use

ignored, the GEAD can be thought of as the more general approach. For this reason, we begin with a description of the GEAD.

We present a more recent derivation of the GEAD developed by Diewert (2015) rather than that of the Tang and Wang (2004) for two reasons. The first is that the multiplicative decomposition of the MFP growth factor provides a "cleaner" separation of the price and reallocation effects than that of Tang and Wang.[6] The second is that Tang and Wang's decomposition is for labour productivity while Diewert (2015) extends the decomposition to multifactor productivity.

Our notation will follow that of Diewert (2015).

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 of 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:

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

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

Each industry has a multifactor productivity level, X_n^t, which is given by the ratio of output in the industry to its input use:

[6] The decomposition in terms of growth rates involves many interaction effects, which makes it difficult to disentangle the role of prices from that of reallocation. In practice, the formulation of Diewert (2015) for growth rates is no "cleaner" than that of Tang and Wang (2004), as it also includes all of the interaction terms.

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

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:

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

This decomposition has a very simple interpretation. The multifactor productivity level of the total economy is equal to the weighted average of the multifactor productivity levels 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 each 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.

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

To complete our 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:

$$= \frac{(p_n^0/w_n^0)(Y_n^0/Z_n^0)(w_n^0 Z_n^0 / \sum_{n=1}^{N} w_n^0 Z_n^0)}{\sum_{n=1}^{N} (p_n^0/w_n^0)(Y_n^0/Z_n^0)(w_n^0 Z_n^0 / \sum_{i=1}^{N} w_i^0 Z_i^0)}$$

$$= \frac{p_n^0 Y_n^0 / \sum_{n=1}^{N} w_n^0 Z_n^0}{\sum_{n=1}^{N} p_n^0 Y_n^0 / \sum_{i=1}^{N} w_n^0 Z_n^0}$$

$$= \frac{p_n^0 Y_n^0}{\sum_{n=1}^{N} p_n^0 Y_n^0}$$

$$\equiv s_{Yn}^0$$

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

Substituting this into our 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:

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

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 15 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:

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

Analagous expressions are used for the contributions of output price growth (Δp_n), (inverse) input price growth (Δw_n), and input cost share growth (Δs_{Zn}).

We calculate contributions from relative output price growth, relative input price growth, and the growth in input shares in an analogous way.

B. The Traditional Decomposition

The GEAD differs from the traditional productivity decomposition (Denison 1962) by including changes in relative prices. Diewert (2015) finds that, in practice, the price and input share terms of the GEAD multifactor productivity decomposition derived are more or less offsetting in the aggregate so that almost all of aggregate MFP growth can be traced to within-sector growth.[7] 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 (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 price changes in our traditional decomposition, we will replace the nominal share of total economy input costs, s_{Zn}^t, associated with each industry with the real share of aggregate input use: $\hat{s}_{Zn}^t$:

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

[7] Diewert (2016) explains why this is so mathematically.

Similarly, we will replace s_{Yn}^0 with $\hat{s}_{Yn}^0$, sector n's share of real output in the total economy:[8]

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

The CSLS of labour productivity rests on assumption that real aggregate output is equal to the sum of the real outputs of each sector (ie. $Y^t = \sum_{n=1}^N Y_n^0$). This 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. In extending the decomposition to MFP, we require a similar assumption that real aggregate input is equal to the sum of the real inputs of each sector (ie. $X^t = \sum_{n=1}^N X_n^0$). 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.

We will call the corresponding growth rate of sector n's share of total economy aggregate input $\hat{\sigma}_n$.

Our "traditional" decomposition[9] of MFP growth by sector is thus:

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

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

The **within-sector effect**: $s_{Yn}^0 \gamma_n$;

The **reallocation level effect**: $s_{Yn}^0 \hat{\sigma}_n$;

And the **reallocation growth effect**: $\hat{s}_{Yn}^0 \gamma_n \hat{\sigma}_n$

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.

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[8] 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.

[9] 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 measure of aggregate input. If a fixed set of prices is used through time to aggregate inputs, then aggregate input can be additively separated into contributions from each input.

There remains disagreement among experts as to whether or not 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 will provide the same within-sector effects if an appropriate base period for the prices is chosen.[10]

In practice, whether or not 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 the real output or "real" productivity of the sector. However, if one is interested in understanding how the value of output generated in the economy per worker 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 worker, it does not matter whether resources are reallocated to industries which 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 the value of output produced per worker has increased.

C. The CSLS Decomposition

A weakness of the traditional decomposition (and of the GEAD decomposition as specified above) is that the allocation of the reallocation effects across sectors is questionable. In particular, the GEAD reallocation effects are such that a sector will have a positive total reallocation effect (sum of the level and growth effects) as long as the input share of the sector increases. Even if the sector has the lowest productivity in the economy, if its share of input costs rises the traditional decomposition will indicate that the sector has increased aggregate productivity. The CSLS decomposition (Sharpe, 2009; Sharpe, 2010; de Avillez, 2012) proposes a more reasonable approach to the reallocation of labour in the decomposition of labour

[10] 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.

productivity. We will extend the CSLS labour productivity decomposition to encompass multifactor productivity.[11]

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:

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

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

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

This can be rewritten as:

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

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

Where $\hat{X}_{n}^{t} = \frac{Y_{n}^{t}}{Z_{n}^{t}}$ 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.[12]

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.

Substituting this expression into the traditional formula we obtain:

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[11] 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.

[12] Note that $\hat{X}_{n}^{t}$=X_{n}^{t}, but we introduce the additional notation because 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}.

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

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 $\left(\frac{\hat{X}_n^1}{\hat{X}^0}\right)$ will be positive, this should make it clear that 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 would be to simply forget about assigning reallocation effects to each industry and simply report a total reallocation effect. Alternatively, we can try to 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.

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	−	+	+	−

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.[13]

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[14] from the traditional decomposition formula:

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

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

This results in the CSLS decomposition of MFP growth:

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

This expression looks extremely 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.

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[13] See the appendix for a discussion of an alternative approach to distributing the reallocation effect among industries which would address this criticism.

[14] This holds 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.

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 will implement the GEAD (equation (1)) and CSLS (equation (3)) decompositions of MFP growth for "business sector industries"[15] in Canada over the 2000-2008 period. The decompositions will provide contributions from each combination of the 10 provinces and 15 2-digit NAICS business sector industries – 150 industry-province pairs in total.

To perform these decompositions, we will utilize data from Statistics Canada. The required data on real and nominal capital services, real and nominal GDP, hours worked, and labour compensation are available in CANSIM Table 383-0026.

The table does not provide aggregates for the all provinces business sector so we must construct them. This is straightforward when the data are in nominal terms or physical units (hours). Our data for the real capital services and real value added are in chained 2002 dollars constructed using Fisher indexes. We construct approximate Fisher chained aggregates for and for the capital stock, real output, and aggregate input in the all provinces business sector following a procedure outlined by Landefeld et al. (2003). In all cases, this involves calculating volume indexes and chaining them to the current dollar value in the reference year.

We also construct aggregate input within each sector rather than using the combined input labour and capital input index used by Statistics Canada. We do not include the effects of labour composition in our labour input and aggregate input while Statistics Canada does. Our aggregate input within each sector is also constructed as a chained Fisher index.[16]

Growth rates of output and aggregate input prices are calculated 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 assumed equal to nominal value added in the sector). Similarly, the growth rates of aggregate output prices in each sector are calculated as the growth rates of the implicit output price deflator.

[15] Data on capital stocks and flows by industry and province are only available for the total economy via CANSIM. We restrict attention to the set of industry associated with the business sector (excludes public administration, education, and health), but our data are not restricted to only business establishments in these sectors. In practice, almost all establishments in our "business sector industries" are business establishments, so we will sometimes refer to this as the business sector.

[16] Note that Statistics Canada aggregates labour and capital input using a Tornqvist-Theil index rather than a Fisher index, which may result in minor differences.

The price levels of capital and labour are required to construct Fisher volume measures of aggregate input.[17] The hourly price of labour is calculated as the total nominal labour compensation paid to labour divided by the number of hours worked. Similarly, the price of capital services is determined by dividing nominal capital compensation by real capital services.[18] Since real capital services levels are calculated by chaining the capital input index to the nominal value of capital services in the reference year, the price of capital is effectively the implicit price deflator of capital services.

Finally, there are some conceptual difficulties with estimating the MFP levels of each sector for the CSLS decomposition. In particular, one can only calculate relative MFP levels and not an absolute MFP level. To estimate our relative MFP levels for each sector, we calculate the ratio of real output to real input in each sector. In calculating input prices, we have assumed that total nominal compensation to labour and capital is equal to nominal value added within each sector. Since we have chained both real input and real output to a common nominal value in the reference year, this implies that MFP will be equalized at 1 across all industries in the reference year – the differences in our relative MFP levels in the CSLS decomposition are only due to differential MFP growth rates in the sectors before and after the reference year (2007). Alternatively, we could have constructed an alternative measure of real input by applying the same national prices of capital and labour in constructing aggregate input in each sector. This would lead to different MFP levels even in the reference year, with all MFP levels expressed relative to the MFP level of the business sector industries aggregate in all provinces in the reference year. While an approach which generates differing MFP levels in the reference year is desirable, we opt to take the simpler approach of using sector-specific prices in constructing aggregate input.[19]

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[17] The relative input price growth rates of labour and capital are also needed for our extension of the GEAD by input in the appendix.

[18] Note that this is an ex-post measure of the price of capital, as it includes profits

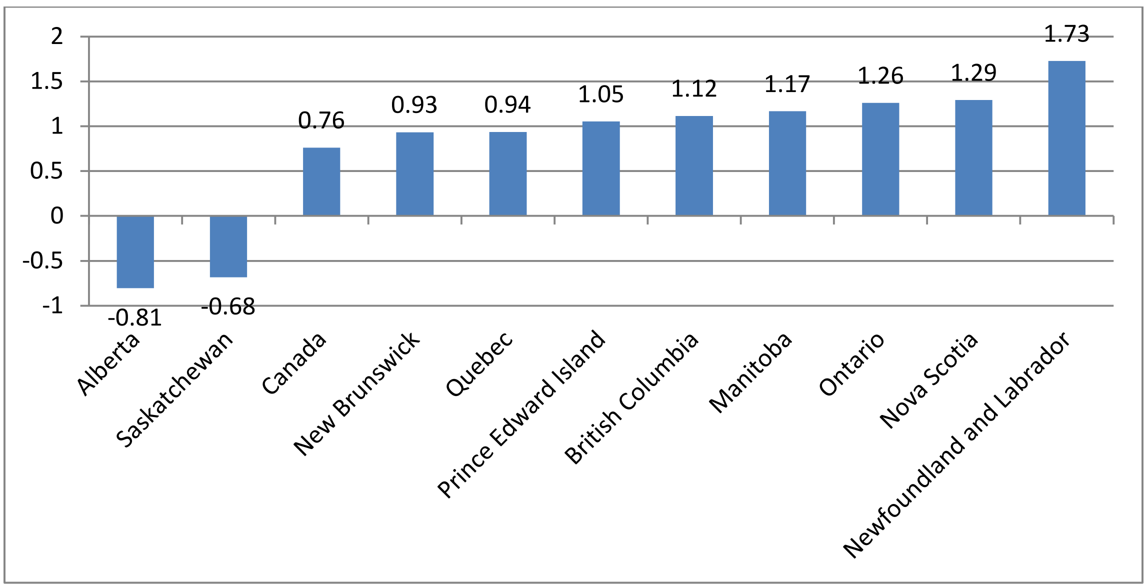
[19] We have experimented with generating results using national input prices to obtain differential MFP levels in the reference year. Doing so does not seem to significantly change our conclusions, although the magnitudes of aggregate MFP growth and the contributions associated with each industry change.

III. Results

A. Overview of Multifactor Productivity 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 growth in MFP 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 will begin with within-sector multifactor productivity.

Chart 2: Multifactor Productivity Growth in Canada and the Provinces, Business Sector Industries, Compound Annual Rate of Change, Per Cent, 1997-2012



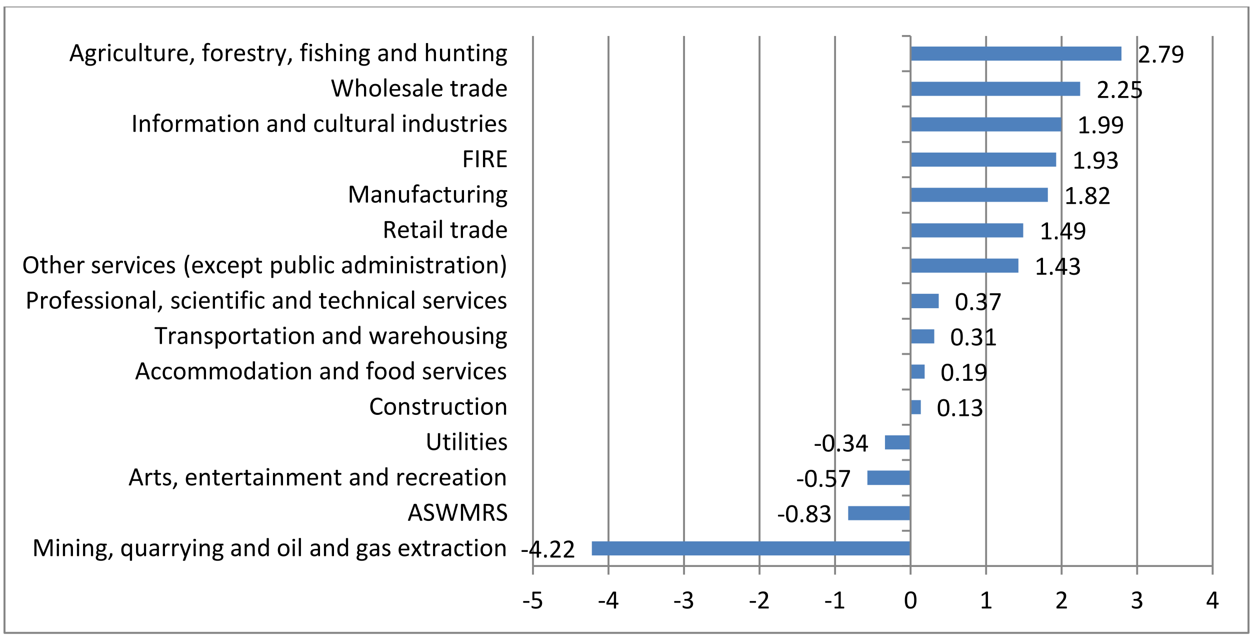
Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

We estimate that aggregate MFP in Canada's business sector industries increased by 12.06 per cent over the 1997-2012 period. This amounts to a growth rate of 0.76 per cent annually. Note that this is considerably higher than the official MFP growth rate of 0.04 per cent annually from Statistics Canada (recall Chart 1, which included this period). Most of this discrepancy can be explained by the fact that we are using capital stock rather to measure capital input while Statistics Canada uses capital services. Diewert and Yu (2012) report that the capital services growth rate from 2000-2011 based on Statistics Canada's methodology was 3.25 per cent annually while the growth rate based on capital stock was only 2.00 – a difference of 1.25 percentage points. Noting that capital's share of compensation is roughly 0.4, this suggests that using capital stock rather than capital services over this period should be expected to raise estimated MFP growth by about 0.5 percentage points. Assuming this gap is representative of that which occurred over the entire 1997-2012 period, this brings us within 0.22 percentage points of Statistics Canada's estimate. The fact that Statistic's Canada adjusts labour input for compositional changes while we do not may explain the remainder of the discrepancy, as changes in labour composition increased labour input over the period.

Over the 1997-2012 period, MFP fell in two provinces: Alberta (-0.81 per cent per year) and Saskatchewan (-0.68 per cent per year). MFP grew modestly in most other provinces. Newfoundland and Labrador stands out with the strongest MFP growth, at 1.73 per cent per year.

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 less lucrative resources as soaring prices made them financially viable. However, the third major oil producing province, Newfoundland and Labrador, experienced the strongest MFP growth of the provinces over the period, which suggests that the effects of the oil and gas boom are more nuanced.[20]

Chart 3: Multifactor Productivity Growth by Business Sector Industry, Compound Annual Rate of Change, Per Cent, 1997-2012



[20] The productivity growth in the oil and gas industry in Newfoundland and Labrador is linked to the nature of the offshore oil production which occurs in the province. Several offshore oil wells began operating in the province in the late 1990s. These offshore wells represented the major capital inputs to the industry in the province, and the capital stock expanded at a much slower pace than that observed in Alberta and Saskatchewan over the 1997-2012 period. Productivity 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).

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

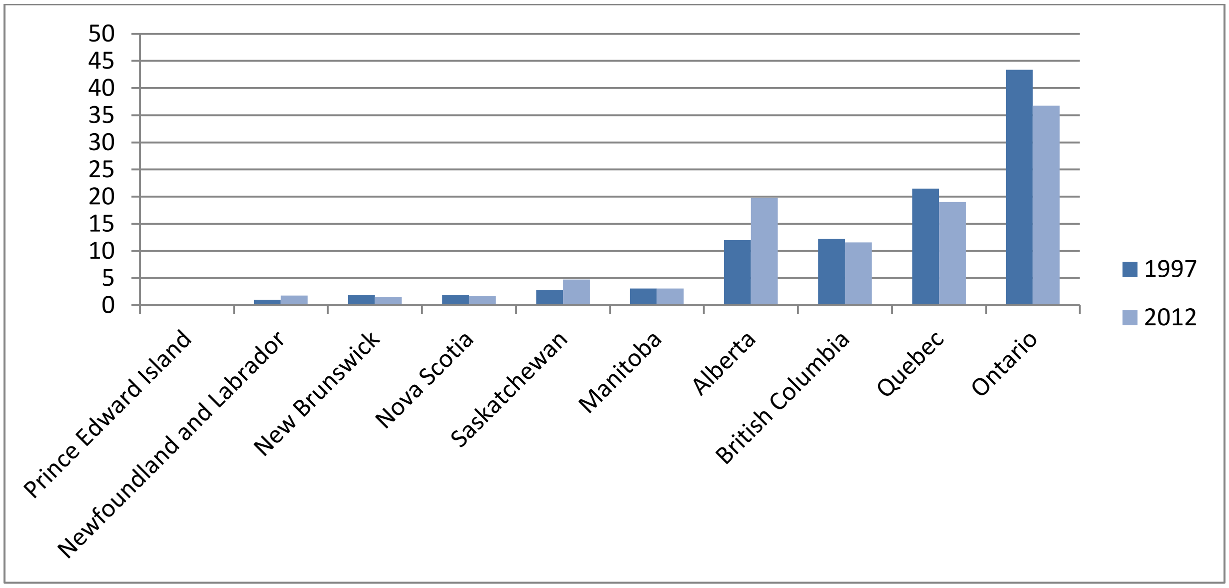
Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

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 2012 (-4.2 per cent annually). MFP also fell in administrative and support, waste management, and remediation services (ASWMRS) (-0.83 per cent per year); arts, entertainment and recreation (-0.57 per cent per year); and utilities (-0.34 per cent per year). Significant MFP growth occurred in agriculture, forestry, fishing, and hunting (2.8 per cent per year); wholesale trade (2.3 per cent per year); information and cultural industries (2.0 per cent); finance, insurance, real estate, and leasing (FIRE) (1.9 per cent per year); and manufacturing (1.8 per cent per year).

The relative sizes of sectors also matter for aggregate productivity. Chart 4 and Chart 5 show the relative sizes of the provinces and industries in terms of nominal value added (assumed equal to the nominal cost of inputs) and how these have changed over time.

Chart 4 makes it clear that the size of each provincial economy is roughly proportional to its population. The most notable feature of Chart 4, however, is that Alberta, Saskatchewan, and Newfoundland and Labrador have experienced massive growth in the sizes of their economies relative to the other provinces, while the three largest provinces (Ontario, Quebec, and British Columbia) have experienced relative declines in size. Ontario's share of nominal GDP in the business sector industries fell from 43.4 per cent in 1997 to 36.8 per cent in 2012 while Alberta's rose from 12.0 per cent to 19.8 per cent.

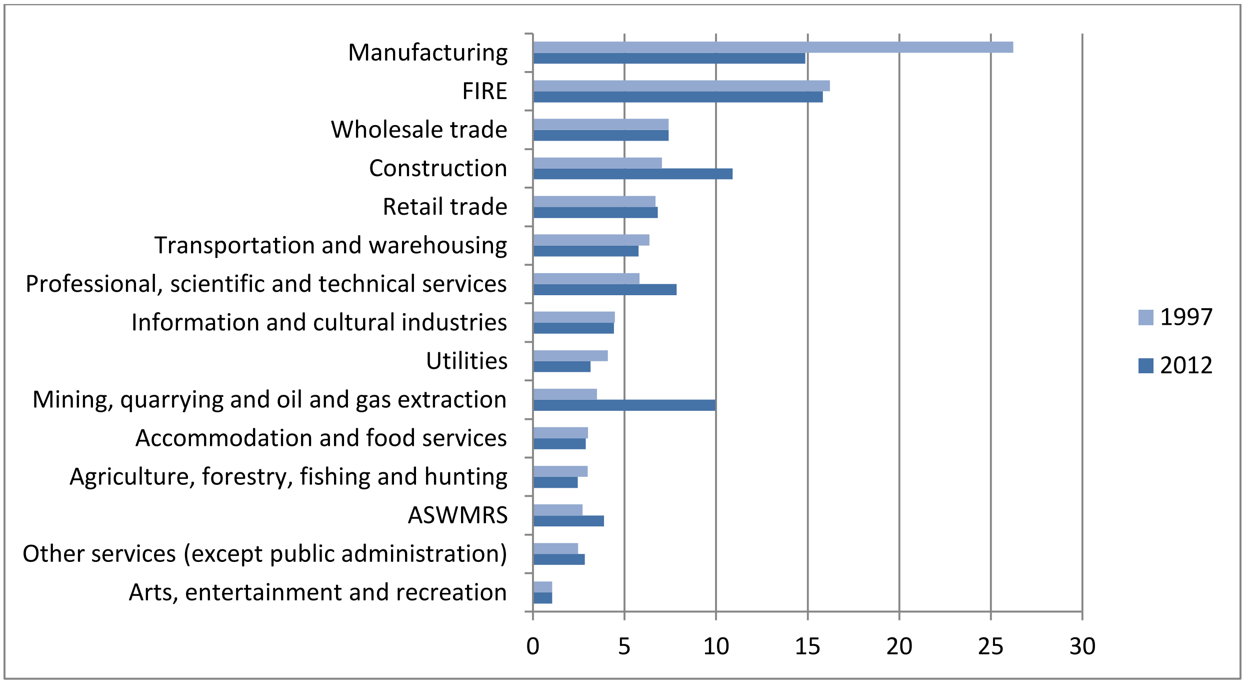
Chart 4: Distribution of Nominal Input Costs (Nominal GDP) across Provinces, All Provinces, Per Cent of All Provinces Total, 1997 and 2012



Source: CSLS Calculations using data from CANSIM Tables 379-0025 and 379-0030.

The relative sizes of Canada's business sector industries have remained fairly stable in most cases, but there are a few notable exceptions. Manufacturing's share of total input costs fell from 26.2 per cent in 1997 to 14.9 per cent in 2012. Meanwhile, mining and oil and gas extraction's share rose from 3.5 per cent to 10.0 per cent and construction's share rose from 7.0 per cent to 10.9 per cent. Given the geographic concentrations of mining and oil and gas and manufacturing, these developments are closely related to the trends observed in Chart 4.

Chart 5: Distribution of Nominal Input Costs across Industries, All Provinces, Per Cent of Business Sector Industries Total, 1997 and 2012



Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 379-0025 and 379-0030.

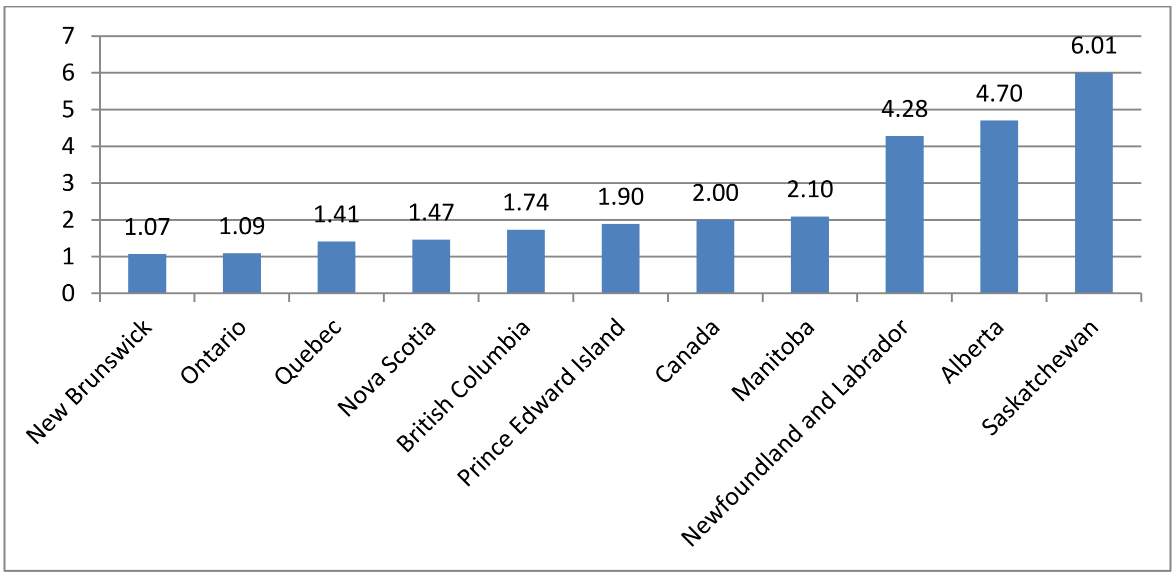
Overall, these trends in multifactor productivity and economic activity suggest that we may expect to find that much of Canada's MFP growth was driven by the expansion of the highly productive mining and oil and gas extraction industries in Alberta, Saskatchewan, and Newfoundland and Labrador. However, falling productivity levels within this sector should be expected to have an offsetting effect and it is not clear which will dominate. The massive decline in the share of the manufacturing sector will also likely have a negative effect under the GEAD (which treats a decline in input share as a negative contribution to productivity), although the sector also experienced strong MFP growth so that the total effect is not immediately clear. In the CSLS decomposition, the net contribution of the manufacturing sector is more likely to be positive because the reallocation effect will only reflect the deviation of manufacturing's productivity level from the national average, a deviation which is not all that large.

B. Input and Output Prices

For the GEAD, we are also concerned about changes in relative prices. If the output of a sector becomes relatively more valuable compared to that of other sectors over time, reflected in a rising relative price of the output of the sector, then the value of output produced on a per worker basis by that sector rises. The aggregate output price growth of the business sector in all provinces was 2.0 per cent annually from 1997 to 2012 based on the implicit GDP deflator (Chart 6). Three provinces experienced significantly above average price growth: Saskatchewan (6.0 per cent per year), Alberta (4.7 per cent per year), and Newfoundland and Labrador (4.3 per cent per year). This reflects the effects of rising natural resource prices. Price growth was relatively modest in the other provinces. The slowest growth in output prices occurred in New Brunswick (1.1 per cent per year), Ontario (1.1 per cent per year) and Quebec (1.4 per cent per year).

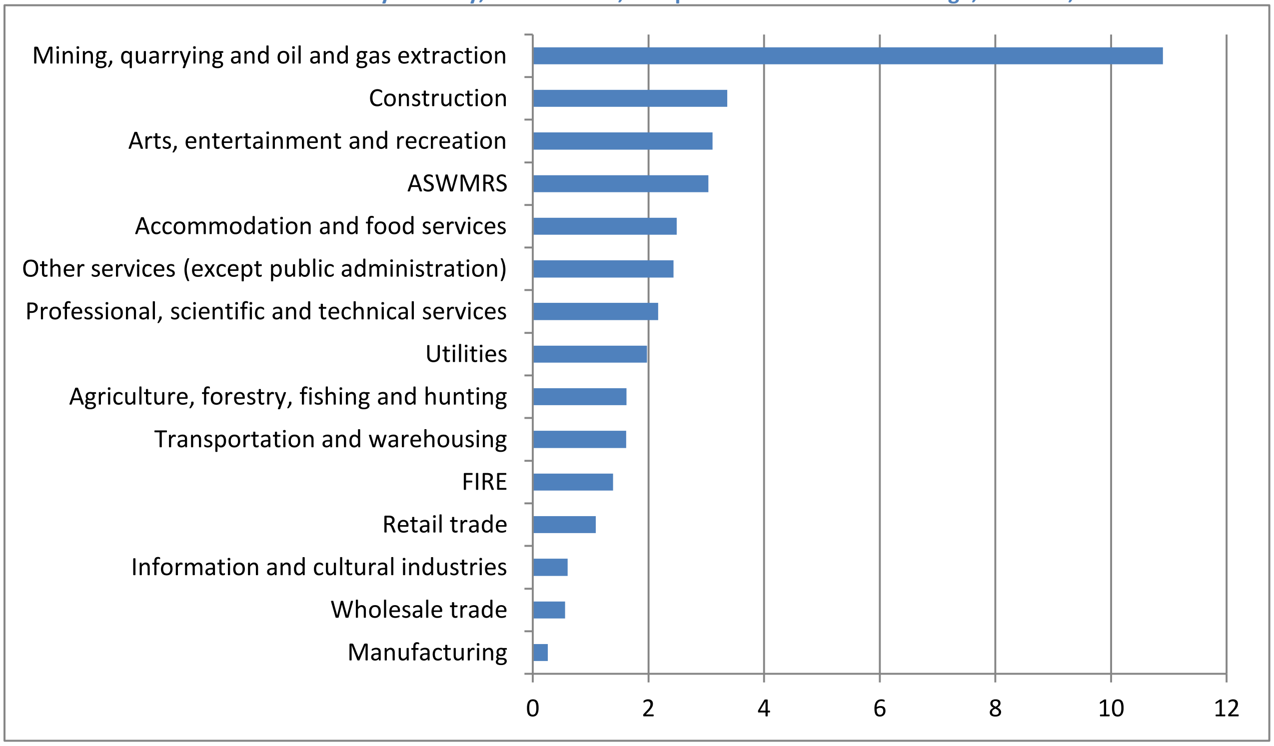
Chart 7 shows that prices rose in mining and oil and gas extraction at an astounding annual rate of 10.9 per cent. This will translate into large MFP growth contributions from the industry in the GEAD. Construction had the second-highest rate of price growth at 3.4 per cent per year. Prices rose most slowly in manufacturing (0.3 per cent per year) and wholesale trade (0.6 per cent per year).

Chart 6: Growth of the GDP Deflator in Business Sector Industries, Canada and the Provinces, Compound Annual Rate of Change, Per Cent, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

Chart 7: Growth of the GDP Deflator by Industry, All Provinces, Compound Annual Rate of Change, Per Cent, 1997-2012



Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

The GEAD framework also accounts for changes in relative input prices. If an input becomes relatively expensive, this suggests that it should be weighted more heavily when assessing aggregate input use. This may reflect changes in the quality of the input (compositional) or the idea that the opportunity cost of using the input has changed (could substitute a greater quantity of other inputs which have become relatively cheaper).

Chart 8 and Chart 9 reveal similar patterns in relative input price growth to those observed in output price growth. For example, input prices have increased the most in Alberta, Saskatchewan, and Newfoundland and Labrador, the same provinces with the fastest output price growth.[21] 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.

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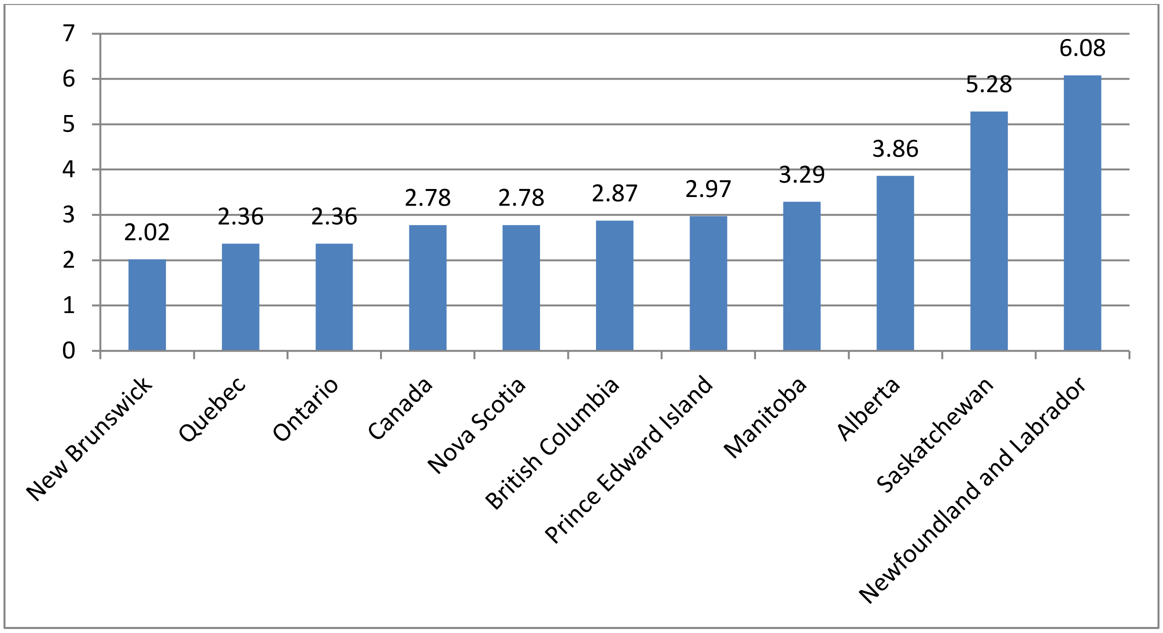
[21] Interestingly, input price growth was considerably stronger in Saskatchewan and Newfoundland and Labrador than it was in Alberta.

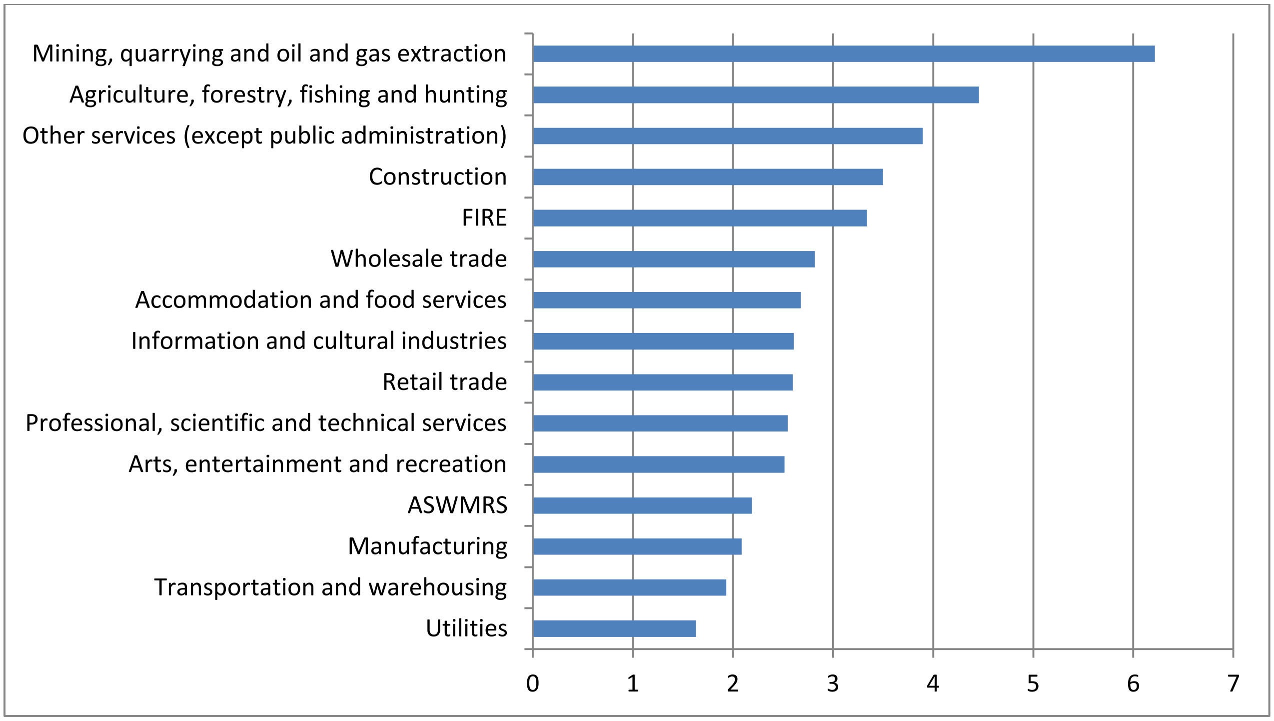
Chart 8: Implicit Input Price Deflator Growth by Province, Compound Annual Rate of Change, Per Cent, 1997-2012



Note: Profits are included in our measure of aggregate input price growth. Our real aggregate input is constructed by constructing Fisher aggregates of capital and labour input using prices based on the nominal compensation received by capital and labour, where the nominal compensation of capital is calculate as the difference between nominal GDP and nominal labour compensation. The implicit price deflator is calculated as the ratio between nominal compensation costs (nominal GDP) and real aggregate input.

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Chart 9: Implicit Input Price Deflator Growth by Industry, Compound Annual Rate of Change, Per Cent, 1997-2012



Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

C. GEAD Decomposition

Table 1 presents the results of the GEAD decomposition, which breaks aggregate MFP growth into contributions from each industry and province. The contributions are presented as percentage points of the aggregate MFP growth between 1997 and 2012. Table 2 presents these contributions as a percentage of the total contribution. Within each industry/province, the total contribution can be split into four effects primarily[22] associated with four factors (within-sector MFP growth, growth in relative output prices, growth in relative input prices, and growth in the sector's share of total input costs).

First, consider the four factors at the aggregate level. Within-sector MFP growth accounts for 101.9 per cent of aggregate MPF growth. This is not surprising, as Diewert (2016) shows that the price and reallocation effects will approximately cancel out when aggregated. Rising relative output prices account for 23.7 per cent of MFP growth, but are more than offset by rising relative

[22] Keep in mind that each of the four components contains an equal share of the factor's interaction effects with the other factors.

input prices (-42.3 per cent). Reallocation of input costs across sectors is responsible for 16.7 per cent of total MFP growth. Since this last term captures nominal input costs, it also captures the effects of changes in relative input prices to some degree.

Now consider how the MFP growth was distributed across the provinces (Chart 10). The GEAD attributes 84.2 per cent of aggregate MFP growth to Alberta, with Saskatchewan contributing 20.2 per cent, and Newfoundland and Labrador 8.3 per cent. This strongly suggests that the oil boom was responsible for all of the productivity growth observed in Canada between 1997 and 2012. Examining the detailed breakdowns within these provinces, we observe that rising output prices and reallocation of inputs towards these provinces were the major sources of productivity growth. Rising input prices in these provinces significantly reduced overall MFP growth as did the falling MFP levels within Saskatchewan and Alberta. The strong MFP growth within Newfoundland and Labrador accounted for 7.2 per cent of aggregate MFP growth. British Columbia and Manitoba also made modest positive contributions to MFP growth.

Based on the GEAD, Ontario was the greatest burden on aggregate MFP growth, lowering it by 18.0 per cent. This was due to falling relative prices for Ontario's products and reallocation of productive resources away from the province. However, productivity growth within Ontario did make a very large positive contribution of 67.4 per cent, much larger than the within-province contributions observed in the other provinces. Quebec, Nova Scotia, and New Brunswick also lowered Canada's MFP growth, but their contributions were relatively minor.

Table 1: Contributions by Province and Business Sector Industry to MFP Growth, GEAD, Percentage Point Contributions, 1997-2012

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Contribution to Aggregate MFP Growth
Total	12.29	2.85	-5.10	2.01	12.06
Alberta	-1.78	7.02	-4.31	9.22	10.15
British Columbia	2.16	-0.35	-0.40	-0.68	0.72
Manitoba	0.57	0.10	-0.31	0.00	0.37
New Brunswick	0.21	-0.19	0.19	-0.39	-0.18
Newfoundland and Labrador	0.87	0.61	-1.71	1.24	1.00
Nova Scotia	0.36	-0.14	-0.01	-0.29	-0.07
Ontario	8.13	-5.60	2.46	-7.15	-2.17
Prince Edward Island	0.05	0.00	-0.01	-0.01	0.02
Quebec	2.85	-1.65	1.25	-2.68	-0.23
Saskatchewan	-1.13	3.05	-2.24	2.75	2.43
Accommodation and food services	0.08	0.22	0.05	-0.14	0.21

ASWMRS	-0.43	0.53	0.29	1.24	1.63
Agriculture, forestry, fishing and hunting	1.24	-0.13	-0.77	-0.59	-0.26
Arts, entertainment and recreation	-0.10	0.18	0.04	0.00	0.12
Construction	0.46	1.88	-1.29	4.13	5.18
Finance, insurance, real estate, rental and leasing	4.88	-1.51	-1.45	-0.40	1.53
Information and cultural industries	1.40	-0.97	0.11	-0.05	0.48
Manufacturing	5.87	-5.49	2.32	-12.26	-9.56
Mining and oil and gas extraction	-6.43	10.66	-5.60	9.04	7.67
Other private services	0.60	0.19	-0.47	0.40	0.72
Professional, scientific and technical services	0.45	0.22	0.14	2.15	2.97
Retail trade	1.59	-0.96	0.18	0.12	0.93
Transportation and warehousing	0.32	-0.36	0.78	-0.63	0.11
Utilities	-0.25	0.03	0.66	-0.99	-0.55
Wholesale trade	2.63	-1.65	-0.11	0.01	0.89

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Table 2: Contributions by Province and Business Sector Industry to MFP Growth, GEAD, Per Cent of Total MFP Growth, 1997-2012

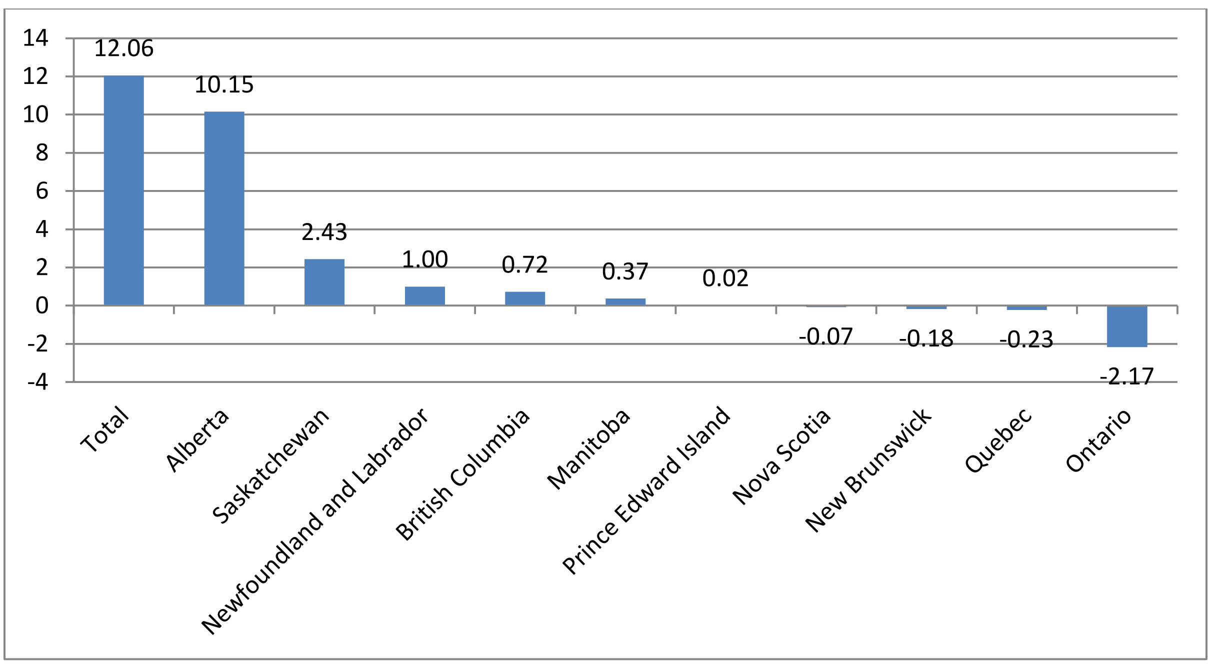
	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Contribution to Aggregate MFP Growth
Total	101.92	23.66	-42.27	16.69	100.00
Alberta	-14.75	58.21	-35.72	76.48	84.22
British Columbia	17.89	-2.87	-3.33	-5.67	6.01
Manitoba	4.76	0.83	-2.57	0.04	3.06
New Brunswick	1.75	-1.57	1.55	-3.20	-1.48
Newfoundland and Labrador	7.19	5.07	-14.21	10.26	8.30
Nova Scotia	3.02	-1.17	-0.04	-2.39	-0.58
Ontario	67.40	-46.45	20.37	-59.29	-17.96
Prince Edward Island	0.38	-0.02	-0.11	-0.11	0.14
Quebec	23.65	-13.69	10.37	-22.21	-1.88
Saskatchewan	-9.35	25.33	-18.57	22.77	20.18
Accommodation and food services	0.70	1.83	0.41	-1.17	1.78
ASWMRS	-3.60	4.42	2.41	10.25	13.48
Agriculture, forestry, fishing and hunting	10.26	-1.07	-6.38	-4.93	-2.12

Arts, entertainment and recreation	-0.82	1.51	0.36	-0.02	1.03
Construction	3.78	15.60	-10.69	34.23	42.93
Finance, insurance, real estate, rental and leasing	40.49	-12.49	-11.99	-3.36	12.66
Information and cultural industries	11.62	-8.05	0.90	-0.45	4.02
Manufacturing	48.67	-45.56	19.27	-101.69	-79.30
Mining and oil and gas extraction	-53.37	88.43	-46.47	75.00	63.59
Other private services	4.95	1.55	-3.88	3.32	5.93
Professional, scientific and technical services	3.69	1.86	1.19	17.87	24.61
Retail trade	13.18	-7.96	1.50	1.01	7.74
Transportation and warehousing	2.62	-3.00	6.47	-5.21	0.89
Utilities	-2.09	0.23	5.51	-8.22	-4.57
Wholesale trade	21.84	-13.66	-0.88	0.05	7.35

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Chart 10: GEAD Contributions to MFP Growth by Province, Percentage Points, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

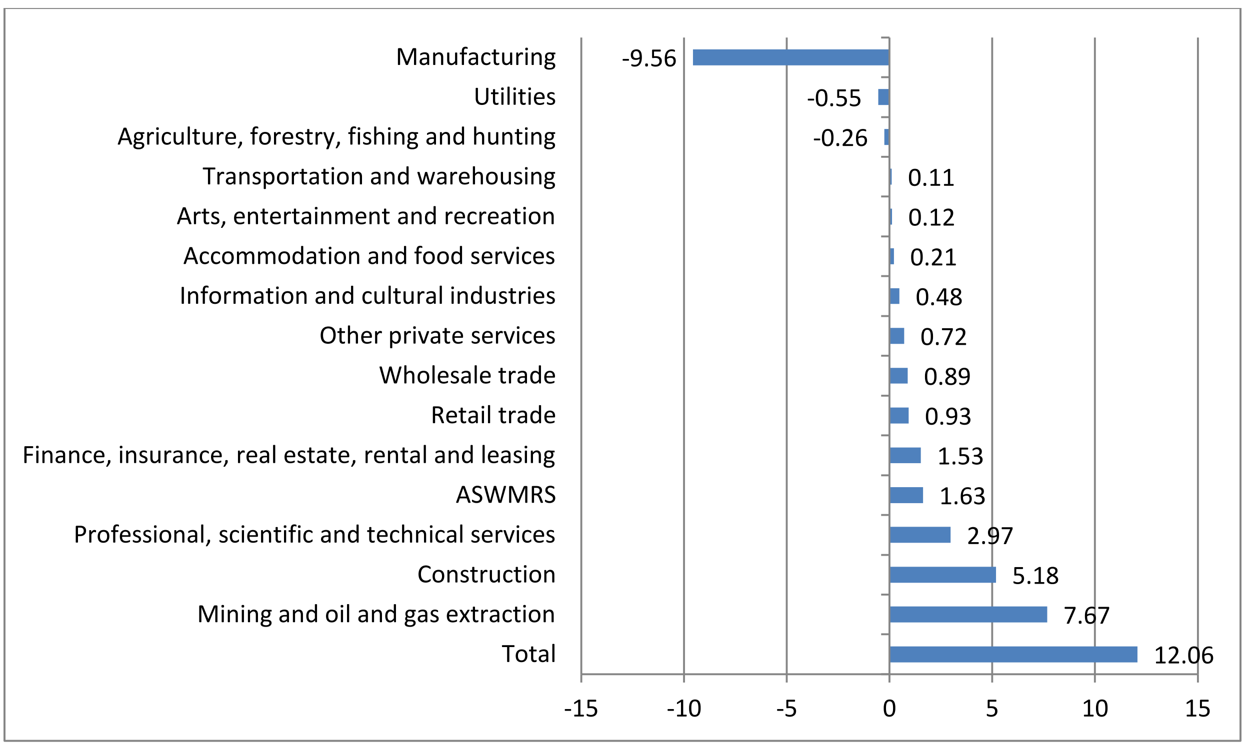
Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

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 (7.67 percentage points or 63.6 per cent of the total). MFP reductions in the industry lowered aggregate MFP growth in the national business sector by 53.4 per cent (-6.43 percentage points) and rising input prices lowered it by 46.5 per cent (-5.60 percentage points), while rising output prices raised MFP growth 88.4 per cent (10.66 percentage points) and reallocation of resources to the sector another 75.0 per cent (9.04 percentage points). It is perhaps more surprising that the contribution of the construction industry was 42.9 per cent of total MFP growth, mostly related to reallocation and output price growth. Professional, scientific, and technical services also contributed 24.6 per cent, mainly due to input reallocation.

Only three sectors made negative contributions to MFP growth: manufacturing, utilities, and agriculture, forestry, fishing, and farming. Of these, manufacturing's contribution of -9.56 percentage points (-79.3 per cent of total growth) was by far the most important. While within-sector MFP growth from manufacturing made a large positive contribution to MFP growth, this was offset by falling relative output prices and a very large negative reallocation effect as the sector's share of nominal input expenditures collapsed.

The sectors which we have highlighted had by far the largest contributions, although several others did have small positive effects on aggregate MFP (Chart 11).

Chart 11: GEAD Contributions to MFP Growth by Industry, Percentage Points, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

We can compare our main results with those of Diewert (2015), who decomposed MFP growth in Australia over the 1995-2012 period. Diewert (2015) 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 even a 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 estimated in Canada. Diewert (2015) 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.

The major trends are clear, but our decomposition at the industry-province level allows for a more detailed analysis of the most important contributions within the most important industries and provinces.

Table 3 presents the 10 industry-province pairs with the largest positive contributions and the 10 with the largest negative contributions to aggregate MFP growth between 1997 and 2012. The three largest negative contributions are from the manufacturing sectors of the three largest provinces. Manufacturing in Ontario alone is associated with a reduction in aggregate MFP growth of 6.99 percentage points (-58.0 per cent of MFP growth). The manufacturing industries in Quebec and British Columbia account for further declines of 2.44 and 0.50 percentage points in total MFP growth, respectively. The utilities industry in Ontario is the fourth largest negative contributor at -0.34 percentage points, arising mainly from reallocation. Agriculture, forestry, fishing, and hunting in British Columbia had a similar effect (-0.33 percentage points) due to reallocation and relative output price declines.

The positive contributions are not as highly concentrated in a few industry-province pairs. It is no surprise that mining and oil and gas extraction in Alberta made the largest positive contribution, although it was only slightly more than one-third of total growth (4.31 percentage points out of 12.06). Construction in Alberta (1.83 percentage points) and construction in Ontario (1.38 percentage points) were the second and third largest positive contributors. It is not surprising that mining and oil and gas extraction in Saskatchewan and Newfoundland and Labrador are also in the top ten. One contribution which merits mention because it does not stand out when examining the aggregated contributions is that FIRE in Ontario had the 9th largest positive contribution at 0.70 percentage points.

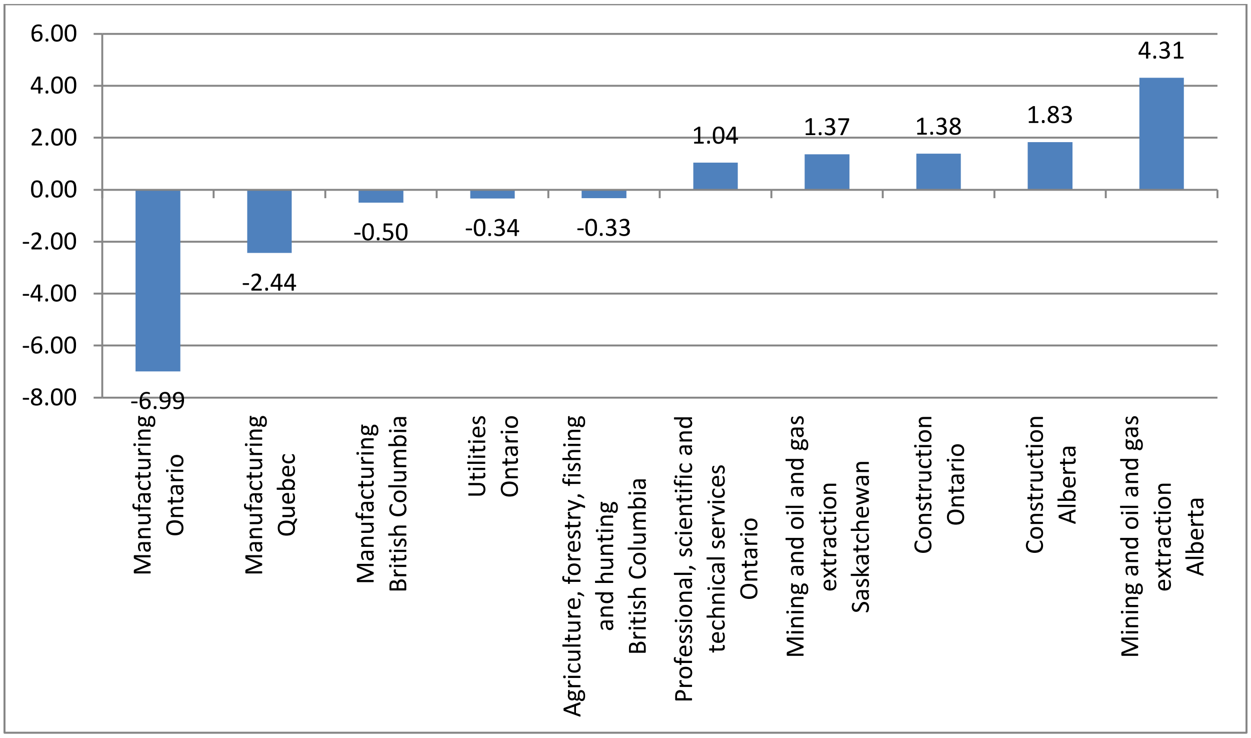
Table 3: Ten Largest Positive and Negative Province-Industry Contributions to MFP Growth, GEAD Decomposition, Percentage Points, 1997-2012

Province	Industry	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Contribution to MFP Growth
Ontario	Manufacturing	3.22	-4.12	2.34	-8.43	-6.99
Quebec	Manufacturing	1.15	-1.34	0.84	-3.09	-2.44
British Columbia	Manufacturing	0.84	-0.44	-0.20	-0.70	-0.50
Ontario	Utilities	-0.06	-0.10	0.32	-0.49	-0.34
British Columbia	Agriculture, forestry, fishing and hunting	0.18	-0.18	0.07	-0.40	-0.33
Quebec	Transportation and warehousing	0.04	-0.16	0.27	-0.29	-0.14
New Brunswick	Manufacturing	0.01	-0.10	0.13	-0.18	-0.14
Nova Scotia	Manufacturing	0.13	-0.09	0.00	-0.16	-0.12
Quebec	Utilities	0.10	0.03	-0.01	-0.22	-0.10
New Brunswick	Wholesale trade	0.04	-0.08	0.06	-0.09	-0.07
Quebec	Professional, scientific and technical services	-0.03	0.07	0.12	0.46	0.62
Ontario	FIRE	2.36	-0.94	-0.51	-0.21	0.70
Newfoundland and Labrador	Mining and oil and gas extraction	0.71	0.60	-1.66	1.15	0.80
Quebec	Construction	0.06	0.11	0.03	0.61	0.82
Alberta	Professional, scientific and technical services	0.32	0.15	-0.35	0.72	0.84
Ontario	Professional, scientific and technical services	0.04	-0.05	0.38	0.68	1.04
Saskatchewan	Mining and oil and gas extraction	-1.92	2.57	-1.26	1.98	1.37
Ontario	Construction	0.13	0.75	-0.53	1.03	1.38
Alberta	Construction	0.17	0.54	-0.50	1.62	1.83
Alberta	Mining and oil and gas extraction	-4.26	5.90	-2.13	4.80	4.31
Total	Total	12.29	2.85	-5.10	2.01	12.06

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Chart 12: Five Largest Positive and Negative Province-Industry Contributions to MFP Growth, GEAD Decomposition, Percentage Points, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

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 4 reveals that the positive productivity contribution of Alberta is not entirely attributable to mining and oil and gas extraction and construction. These two industries are only responsible for 60.5 per cent of Alberta's total contribution. Every other industry in the province also makes a positive effect. These positive effects are not always the result of rising output prices and reallocation, which may be viewed as spillovers from the oil and gas industry. For example, the largest source of FIRE's positive contribution is rising MFP within the sector.

Table 4: Alberta's Contributions to All Province MFP Growth by Business Sector Industry, GEAD Decomposition, Per Cent of Alberta's Total Contribution, 1997-2012

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Contribution to MFP Growth
Accommodation and food services	0.26	0.68	-0.41	0.88	1.42
ASWMRS	-0.55	1.07	0.00	3.12	3.64
Agriculture, forestry, fishing and hunting	2.51	0.27	-2.32	0.10	0.56
Arts, entertainment and recreation	-0.20	0.27	0.06	0.08	0.22
Construction	1.68	5.34	-4.93	15.96	18.04
FIRE	6.44	-0.53	-3.94	4.11	6.08
Information and cultural industries	1.85	-1.26	0.04	0.58	1.20
Manufacturing	3.19	4.11	-5.14	1.96	4.12
Mining and oil and gas extraction	-41.91	58.09	-20.98	47.27	42.46
Other private services	1.28	0.42	-1.26	1.95	2.38
Professional, scientific and technical services	3.17	1.52	-3.49	7.09	8.30
Retail trade	3.48	-0.99	-1.52	3.09	4.06
Transportation and warehousing	0.87	0.46	-0.18	2.22	3.37
Utilities	-1.26	0.33	1.39	-0.37	0.09
Wholesale trade	1.67	-0.66	0.27	2.78	4.06
Total	-17.52	69.11	-42.41	90.82	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

In contrast, the negative contribution of Ontario is exclusively due to the manufacturing sector, which accounts for 322.8 per cent of the province's negative contribution (Table 5). Aside from utilities (15.5 per cent) and agriculture, forestry, fishing, and hunting (2.1 per cent), all industries in Ontario contribute positively to national MFP growth. Construction and professional, scientific, and technical services already appeared in the top five largest positive contributions, but Table 5 reveals that FIRE, ASWMRS, information and cultural industries, wholesale trade, and mining and oil and gas extraction also make sizable positive contributions.

Table 5: Ontario's Contributions to All Province MFP Growth by Business Sector Industry, GEAD Decomposition, Per Cent of Ontario's Total Contribution, 1997-2012

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Contribution to MFP Growth
Accommodation and food services	-4.32	-3.42	2.18	1.60	-3.95
ASWMRS	14.35	-7.65	-14.96	-19.45	-27.72
Agriculture, forestry, fishing and hunting	-12.44	1.84	7.42	5.27	2.09
Arts, entertainment and recreation	0.83	-2.93	-0.32	0.71	-1.71
Construction	-6.17	-34.69	24.44	-47.47	-63.89
FIRE	-109.09	43.56	23.49	9.65	-32.41
Information and cultural industries	-22.72	16.13	-3.75	-8.04	-18.38
Manufacturing	-148.57	190.20	-107.92	389.08	322.79
Mining and oil and gas extraction	15.49	-22.06	4.57	-10.04	-12.04
Other private services	-9.42	-1.35	5.30	-2.70	-8.17
Professional, scientific and technical services	-1.62	2.46	-17.48	-31.34	-47.98
Retail trade	-23.53	23.97	-14.68	11.34	-2.90
Transportation and warehousing	4.75	1.74	-17.72	7.85	-3.38
Utilities	2.77	4.71	-14.60	22.64	15.51
Wholesale trade	-75.49	46.04	10.65	0.94	-17.86
Total	-375.20	258.55	-113.38	330.03	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Within the manufacturing industry, we find that the negative contribution is very highly concentrated in Ontario and Quebec, which together account for 98.6 per cent of the total contribution of the sector (Table 6). Manufacturing actually makes positive contributions to aggregate MFP growth in all three prairie provinces. This may in part be due to increased demand for manufactured products used to support oil and gas production in Alberta and Saskatchewan.

Mining and oil and gas extraction consistently have a non-negative effect on aggregate MFP growth in every province (Table 7). While the effects are concentrated in Alberta, Saskatchewan, and Newfoundland and Labrador, the other seven provinces account for about 15 per cent of the industry's positive growth contribution. Newfoundland and Labrador stands out as the only province in which the within-sector MFP growth contribution is positive.

Table 6: Manufacturing's Contributions to All Province MFP Growth by Province, GEAD Decomposition, Per Cent of the Industry's Total Contribution, 1997-2012

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Contribution to MFP Growth
Alberta	-3.39	-4.36	5.46	-2.08	-4.37
British Columbia	-8.77	4.57	2.10	7.36	5.25
Manitoba	-1.21	-1.10	1.68	-0.16	-0.79
New Brunswick	-0.15	1.06	-1.34	1.89	1.45
Newfoundland and Labrador	0.02	0.45	-0.61	0.60	0.46
Nova Scotia	-1.36	0.99	-0.02	1.67	1.27
Ontario	-33.65	43.08	-24.45	88.14	73.12
Prince Edward Island	-0.05	0.16	-0.16	0.12	0.07
Quebec	-12.04	14.04	-8.79	32.31	25.51
Saskatchewan	-0.76	-1.43	1.84	-1.62	-1.97
Total	-61.37	57.45	-24.30	128.22	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Table 7: Mining and Oil and Gas Extraction's Contributions to All Province MFP Growth by Province, GEAD Decomposition, Per Cent of the Industry's Total Contribution, 1997-2012

	Within-Sector MFP Growth	Relative Output Price Growth	(Inverse) Relative Input Price Growth	Input Share Growth	Total Contribution to MFP Growth
Alberta	-55.51	76.93	-27.79	62.60	56.24
British Columbia	-3.31	6.76	-3.38	7.09	7.16
Manitoba	-0.75	1.58	-0.71	1.56	1.69
New Brunswick	-0.98	1.14	-0.15	0.37	0.38
Newfoundland and Labrador	9.25	7.88	-21.67	15.00	10.47
Nova Scotia	-0.08	0.22	-0.08	-0.02	0.04
Ontario	-4.37	6.23	-1.29	2.84	3.40
Prince Edward Island	0.00	0.00	0.00	0.00	0.00
Quebec	-3.10	4.86	-1.56	2.62	2.82
Saskatchewan	-25.08	33.46	-16.45	25.89	17.81
Total	-83.93	139.07	-73.08	117.94	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

D. CSLS Decomposition

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.

Table 8 and Table 9 present the main results of the CSLS decomposition in absolute and relative terms. The decomposition is not exactly additive so we have rescaled the contributions to sum to aggregate MFP growth.[23] The results indicate that MFP growth within each industry accounted for 127 per cent of aggregate MFP growth.

Reallocation of resources into sectors with higher productivity levels also contributed 75 per cent to MFP growth. Notice that this reallocation effect was positive in almost all industries and provinces, likely because the market tends to reallocate resources towards sectors with above average productivity levels. However, falling MFP levels within the sectors which were gaining resources more than offset the reallocation level effect, halving aggregate MFP growth. Again, this effect is negative in almost all sectors which likely reflects diminishing marginal returns.

The roles of the two major contributors to aggregate productivity performance in the GEAD are reversed in the CSLS decomposition. While the GEAD found that Alberta and the mining and oil and gas extraction industry were responsible for most of the productivity growth in Canada's business sector industries, the CSLS decomposition finds that the contributions of these sectors of the economy greatly reduced MFP growth. Alberta lowered MFP growth by approximately one-third due to falling MFP within the province. The total reallocation effect in

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[23] This adjustment is common when presenting results of non-additive productivity growth decompositions. The unadjusted contributions sum to aggregate MFP growth of 9.4 per cent over the period compared to the actual MFP growth of 12.1 per cent.

Alberta is negative in the CSLS decomposition because of a very large reallocation growth effect (-6.38 percentage points) which more than offset the reallocation level effect. Saskatchewan is now the only other province with a negative contribution. The mining and oil and gas extraction industry is found to have reduced aggregate MFP growth by 10.0 percentage points (83 per cent of the total).

Table 8: Contributions by Province and Business Sector Industry to MFP Growth, CSLS Decomposition, Percentage Point Contributions, 1997-2012

	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total Contribution to MFP Growth
Total	15.30	9.07	-12.31	12.06
Alberta	-3.30	5.44	-6.38	-4.24
British Columbia	2.98	0.84	-1.21	2.61
Manitoba	0.74	0.09	-0.19	0.65
New Brunswick	0.24	0.04	-0.06	0.21
Newfoundland and Labrador	0.75	-0.17	0.02	0.60
Nova Scotia	0.50	0.06	-0.12	0.44
Ontario	9.95	1.13	-2.07	9.02
Prince Edward Island	0.06	0.00	-0.01	0.05
Quebec	3.81	0.46	-0.64	3.62
Saskatchewan	-0.44	1.18	-1.66	-0.91
Accommodation and food services	0.12	0.00	0.00	0.11
Administrative and support, waste management and remediation services	-0.43	0.26	-0.47	-0.64
Agriculture, forestry, fishing and hunting	1.61	0.25	-0.45	1.41
Arts, entertainment and recreation	-0.12	0.03	-0.03	-0.12
Construction	0.47	-0.04	-0.23	0.20
Finance, insurance, real estate, rental and leasing	6.44	0.13	-0.47	6.09
Information and cultural industries	1.59	0.01	-0.03	1.58
Manufacturing	7.80	1.16	-1.84	7.11
Mining and oil and gas extraction	-8.55	6.93	-8.39	-10.02
Other private services	0.75	0.01	-0.01	0.74
Professional, scientific and technical services	0.46	0.15	-0.17	0.44
Retail trade	1.89	-0.03	0.05	1.91
Transportation and warehousing	0.40	0.02	-0.06	0.35
Utilities	-0.25	0.02	-0.01	-0.23
Wholesale trade	3.13	0.18	-0.20	3.11

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: Contributions have been scaled so that the contributions sum to the calculated MFP growth rate. The original unadjusted sum was 9.4.

At the same time, Ontario and the manufacturing industry are found to have been the largest positive contributors to aggregate MFP growth under the CSLS decomposition while they were the largest negative contributors under the GEAD. According to the CSLS decomposition, Ontario explains three-quarters of the observed MFP growth because of rising MFP within the province. Ontario's total reallocation effect is negative. Manufacturing accounts for 65 per cent of aggregate MFP growth, also all from increases to within-sector productivity.

Table 9: Contributions by Province and Business Sector Industry to MFP Growth, CSLS Decomposition, Per Cent of Total MFP Growth, 1997-2012

	Within -Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total Contribution to MFP Growth
Total	126.93	75.21	-102.14	100.00
Alberta	-27.36	45.09	-52.92	-35.19
British Columbia	24.74	6.95	-10.02	21.67
Manitoba	6.16	0.77	-1.57	5.35
New Brunswick	2.00	0.31	-0.54	1.77
Newfoundland and Labrador	6.25	-1.41	0.17	5.01
Nova Scotia	4.16	0.47	-0.97	3.67
Ontario	82.55	9.37	-17.14	74.79
Prince Edward Island	0.51	0.03	-0.09	0.45
Quebec	31.57	3.81	-5.33	30.05
Saskatchewan	-3.66	9.83	-13.75	-7.57
Accommodation and food services	0.99	-0.03	-0.01	0.95
Administrative and support, waste management and remediation services	-3.56	2.17	-3.92	-5.30
Agriculture, forestry, fishing and hunting	13.32	2.08	-3.73	11.67
Arts, entertainment and recreation	-0.97	0.25	-0.28	-0.99
Construction	3.92	-0.35	-1.88	1.68
Finance, insurance, real estate, rental and leasing	53.41	1.04	-3.92	50.53
Information and cultural industries	13.21	0.12	-0.24	13.09
Manufacturing	64.67	9.61	-15.27	59.01
Mining and oil and gas extraction	-70.93	57.48	-69.62	-83.07
Other private services	6.18	0.05	-0.05	6.17
Professional, scientific and technical services	3.83	1.22	-1.38	3.68
Retail trade	15.67	-0.29	0.44	15.82
Transportation and warehousing	3.31	0.14	-0.52	2.92
Utilities	-2.06	0.18	-0.07	-1.95

Wholesale trade	25.93	1.53	-1.68	25.79

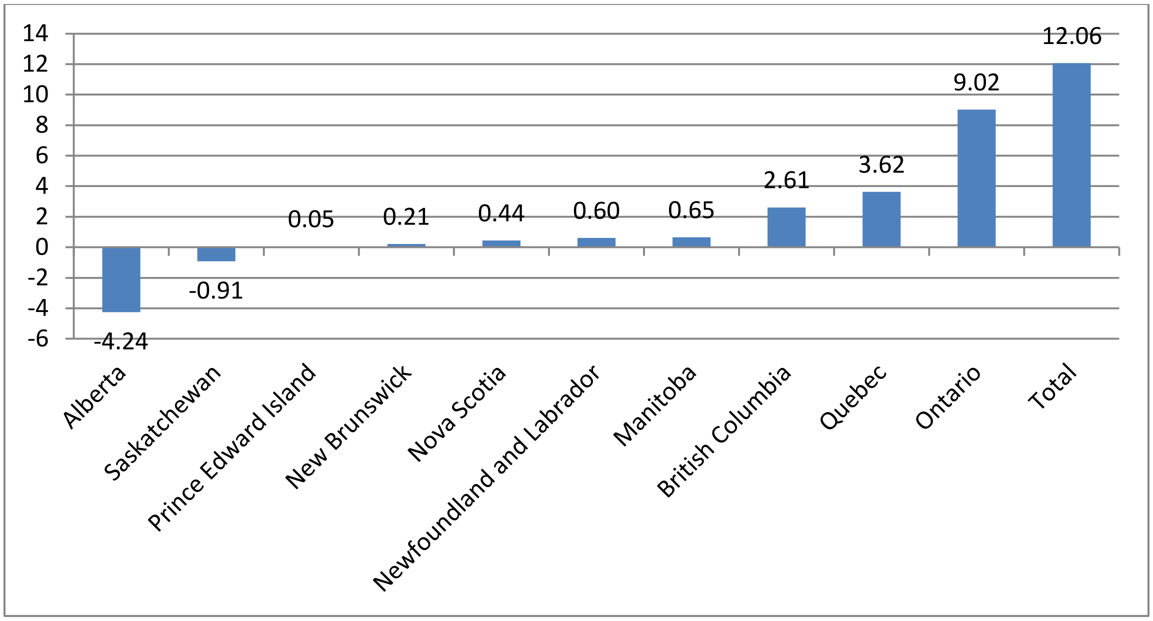
Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note that the CSLS and GEAD decompositions generally agree about the directions of the major within-sector effects,[24] The major differences in the total contributions associated with each sector arise because changes in prices have a large effect if included (they are in the GEAD) and the CSLS decomposition's approach to reallocation effects only considers reallocation to have 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).

A few other provinces and industries are worth highlighting. Quebec is found to have contributed 30 per cent of total MFP growth and British Columbia 22 per cent. In both these provinces, the within-province effects more than explained these positive contributions. Utilities, ASWMRS, and arts, entertainment, and recreation were the only industries other than mining and oil and gas extraction which lowered MFP growth, but the effects were modest. The finance, insurance, real estate, and leasing industry made a very large positive contribution (50 per cent) to productivity growth, all of which was the result of the within-sector effect. There were also sizable contributions from wholesale trade (26 per cent), retail trade (16 per cent), information and cultural industries (13 per cent), and agriculture, forestry, fishing, and hunting (12 per cent).

[24] 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 which Statistics Canada uses in its CANSIM tables, but the CSLS decomposition and the GEAD should only be expected to yield the same within-sector effects if the reference year for prices is 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.

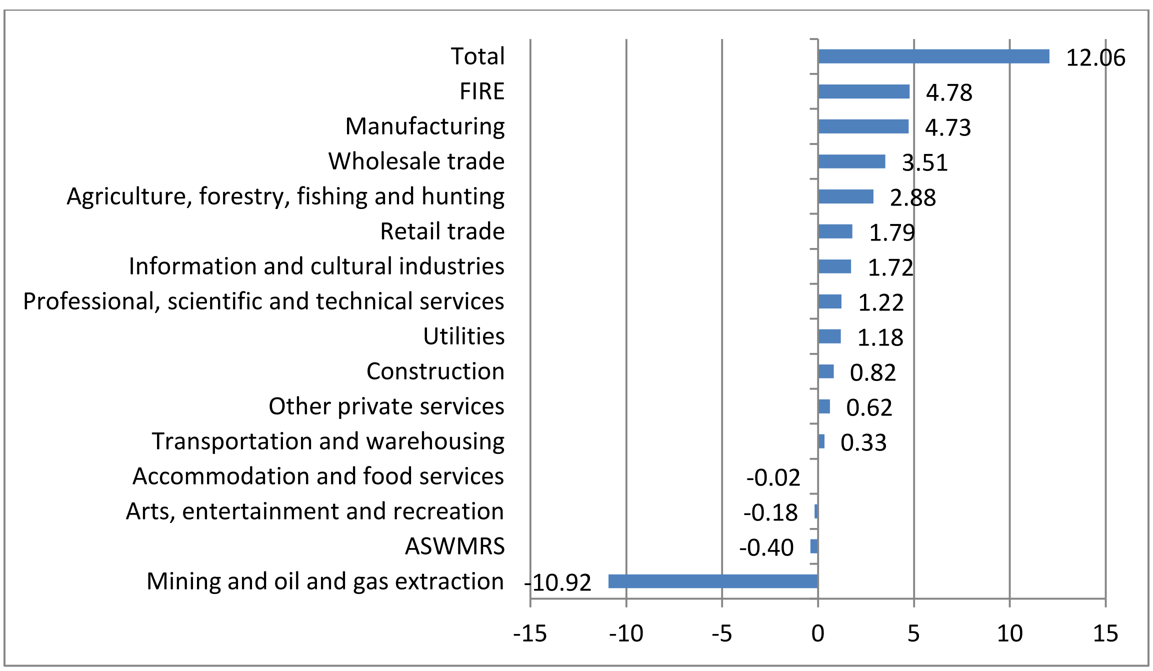
Chart 13: CSLS Contributions to MFP Growth by Province, Percentage Points, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Chart 14: CSLS Contributions to MFP Growth by Industry, Percentage Points, 1997-2012



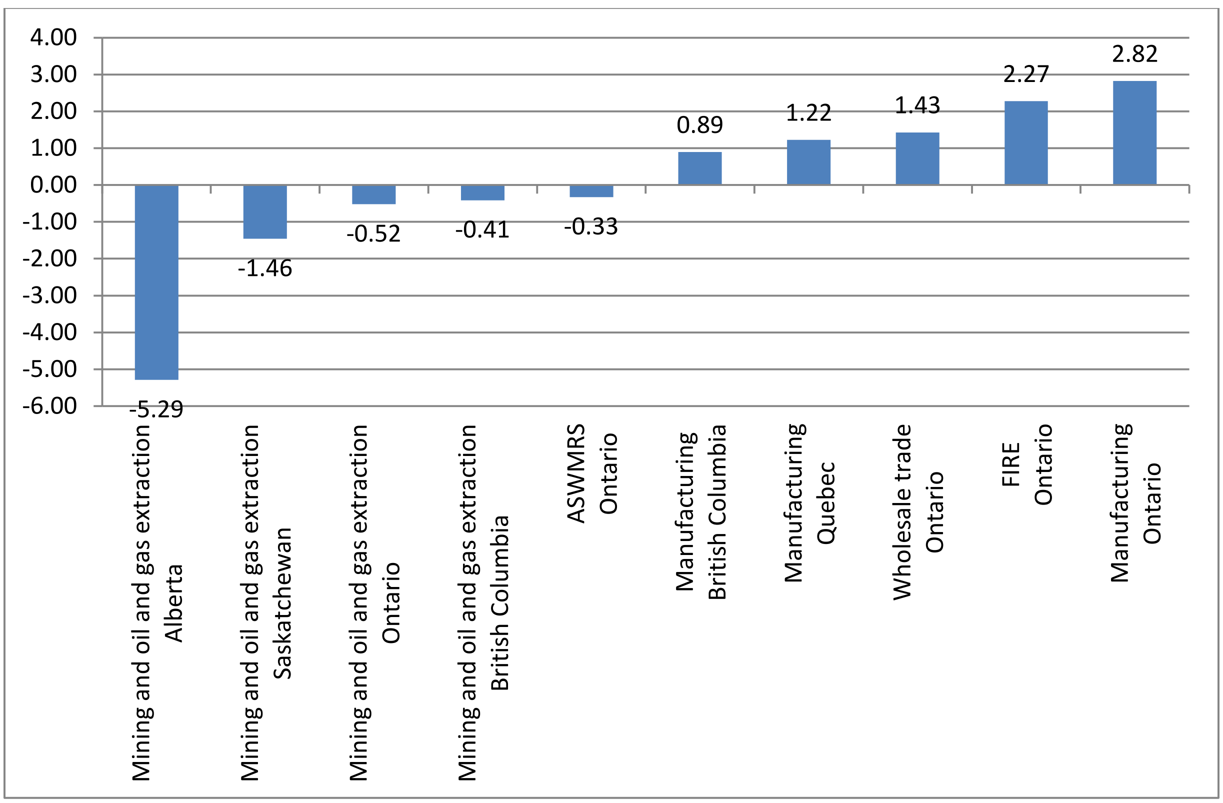
Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Mimicking our analysis of the GEAD in the previous section, we consider the ten largest positive and negative industry-province contributions in Table 10. The four largest negative contributions in the CSLS decomposition are all from the mining and oil and gas extraction industry in the provinces of Alberta (-5.29 percentage points), Saskatchewan (-1.46), Ontario (-0.52), and British Columbia (-0.41). Note the absence of mining and oil and gas extraction in Newfoundland and Labrador from this list, which actually had a small positive contribution due to rising within-sector productivity. The fifth largest negative contribution was from the administrative and support, waste management and remediation services industry of Ontario (-0.33 percentage points).

The three largest positive effects were all in Ontario – manufacturing (2.82 percentage points), FIRE (2.27 percentage points), and wholesale trade (1.43 percentage points). The top five are rounded out by the manufacturing industries of Quebec (1.22 percentage points) and British Columbia (0.89 percentage points). There were also significant contributions from FIRE in British Columbia, Alberta, and Quebec, and from retail trade and information and cultural industries in Ontario.

Chart 15: Five Largest Positive and Negative Province-Industry Contributions to MFP Growth, CSLS Decomposition, Percentage Points, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Within Alberta, we observe that there is considerable variation across sectors in terms of the direction of the contribution (Table 11). This is in contrast to the GEAD which suggested that all sectors in Alberta made positive contributions. The mining and oil and gas sector was clearly the dominant factor in Alberta's large negative contribution, accounting for 160 per cent of it. FIRE, retail trade, manufacturing, professional, scientific, and technical services, wholesale trade, and agriculture, forestry, fishing, and hunting all made notable positive contributions which exceeded (negative) five per cent of the province's total contribution.

Table 10: Ten Largest and Smallest Contributions to MFP Growth, CSLS Decomposition, Percentage Points, 1997-2012

Province	Industry	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total
Alberta	Mining and oil and gas extraction	-4.81	4.34	-4.82	-5.29
Saskatchewan	Mining and oil and gas extraction	-1.13	0.87	-1.20	-1.46
Ontario	Mining and oil and gas extraction	-0.47	0.08	-0.13	-0.52
British Columbia	Mining and oil and gas extraction	-0.30	0.20	-0.30	-0.41
Ontario	ASWMRS	-0.24	0.14	-0.22	-0.33
Quebec	Mining and oil and gas extraction	-0.21	0.03	-0.06	-0.25
Alberta	Utilities	-0.12	0.04	-0.04	-0.12
Manitoba	Mining and oil and gas extraction	-0.08	0.03	-0.06	-0.12
Ontario	Transportation and warehousing	-0.09	0.02	-0.03	-0.11
British Columbia	Accommodation and food services	-0.10	0.00	0.00	-0.10
Ontario	Information and cultural industries	0.40	0.00	0.03	0.43
Ontario	Retail trade	0.48	0.00	0.00	0.48
Quebec	FIRE	0.59	-0.02	-0.02	0.54
Alberta	FIRE	0.67	0.00	0.00	0.67
British Columbia	FIRE	0.88	0.06	-0.14	0.79
British Columbia	Manufacturing	0.94	0.26	-0.31	0.89
Quebec	Manufacturing	1.23	0.19	-0.19	1.22
Ontario	Wholesale trade	1.45	0.05	-0.08	1.43
Ontario	FIRE	2.37	0.05	-0.14	2.27
Ontario	Manufacturing	3.24	0.45	-0.86	2.82
Total	Total	15.30	9.07	-12.31	12.06

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Within Ontario, contributions were positive for most industries (Table 12). The exceptions include ASWMRS, mining and oil and gas extraction, transportation and warehousing, utilities, and arts entertainment, and recreation. Most of the province's overall positive contribution occurred in FIRE (32 per cent), manufacturing (40 per cent), and wholesale trade (20 per cent), although retail trade and information and cultural industries also had non-negligible effects.

Table 11: Alberta's Contributions to All Province MFP Growth by Business Sector Industry, CSLS Decomposition, Per Cent of Alberta's Total Contribution, 1997-2012

	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total Contribution to MFP Growth
Accommodation and food services	-0.77	-0.08	0.07	-0.77
ASWMRS	1.12	-1.00	2.21	2.33
Agriculture, forestry, fishing and hunting	-7.46	-1.44	2.45	-6.45
Arts, entertainment and recreation	0.61	-0.13	0.12	0.60
Construction	-3.95	4.18	1.75	1.98
FIRE	-20.18	0.02	-0.06	-20.23
Information and cultural industries	-4.87	0.23	-0.34	-4.98
Manufacturing	-9.30	0.06	0.49	-8.75
Mining and oil and gas extraction	145.35	-131.29	145.77	159.83
Other private services	-3.38	0.33	-0.39	-3.44
Professional, scientific and technical services	-7.44	1.34	-1.67	-7.77
Retail trade	-9.00	0.83	-1.17	-9.34
Transportation and warehousing	-2.23	0.31	0.20	-1.72
Utilities	3.51	-1.10	1.31	3.72
Wholesale trade	-4.23	-0.41	-0.37	-5.02
Total	77.76	-128.13	150.37	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Table 12: Ontario's Contributions to All Province MFP Growth by Business Sector Industry, CSLS Decomposition, Per Cent of Ontario's Total Contribution, 1997-2012

	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total Contribution to MFP Growth
Accommodation and food services	1.37	-0.07	0.03	1.32
ASWMRS	-3.40	1.93	-3.18	-4.65
Agriculture, forestry, fishing and hunting	3.73	0.53	-1.06	3.19
Arts, entertainment and recreation	-0.24	-0.02	0.02	-0.24
Construction	1.67	0.09	-0.50	1.26
FIRE	33.63	0.67	-1.97	32.32
Information and cultural industries	5.75	-0.07	0.42	6.10
Manufacturing	46.03	6.37	-12.29	40.11
Mining and oil and gas extraction	-6.70	1.08	-1.81	-7.44
Other private services	2.87	0.07	-0.07	2.87
Professional, scientific and technical services	0.39	1.17	-1.37	0.19
Retail trade	6.80	-0.04	0.05	6.81
Transportation and warehousing	-1.35	0.28	-0.44	-1.51
Utilities	-0.83	-0.20	0.40	-0.64
Wholesale trade	20.67	0.75	-1.13	20.28
Total	110.38	12.53	-22.91	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Table 13 provides a breakdown of the contribution of manufacturing by province. The industry made positive contributions to aggregate productivity in all provinces except for Newfoundland and Labrador where the contribution was almost zero. The positive contribution of manufacturing was concentrated in the most populous provinces where the manufacturing sector is also most concentrated. Half of the positive contribution from manufacturing occurred in Ontario, 22 per cent in Quebec, and 16 per cent in British Columbia. The total reallocation effects were consistently negative so that the positive contribution was due to rising within-industry MFP in all provinces.

Table 13: Manufacturing's Contributions to All Province MFP Growth by Province, CSLS Decomposition, Per Cent of the Industry's Total Contribution, 1997-2012

	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total Contribution to MFP Growth
Alberta	5.55	-0.04	-0.29	5.22
British Columbia	17.00	4.61	-5.54	16.08
Manitoba	2.40	-0.01	-0.30	2.08
New Brunswick	0.24	-0.06	0.06	0.24
Newfoundland and Labrador	-0.03	0.00	0.00	-0.02
Nova Scotia	2.69	0.34	-0.83	2.20
Ontario	58.34	8.07	-15.58	50.83
Prince Edward Island	0.07	0.00	0.00	0.07
Quebec	22.09	3.35	-3.39	22.05
Saskatchewan	1.26	0.02	-0.03	1.25
Total	109.60	16.28	-25.88	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Similarly, finance, insurance, real estate, and leasing (FIRE) made a positive contribution within every province which was also entirely due to a positive within-sector effect in every province except for Alberta which had a very minor positive reallocation effect (Table 14). The positive contribution from FIRE was also concentrated in the more populous provinces, with 48 per cent in Ontario, 17 per cent in British Columbia, 14 per cent in Alberta, and 11 per cent in Quebec.

Table 14: Finance Insurance and Real Estate's Contributions to All Province MFP Growth by Province, CSLS Decomposition, Per Cent of the Industry's Total Contribution, 1997-2012

	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total Contribution to MFP Growth
Alberta	14.06	-0.01	0.04	14.09
British Columbia	18.48	1.17	-2.92	16.73
Manitoba	2.65	0.02	-0.22	2.44
New Brunswick	1.83	0.09	-0.28	1.64
Newfoundland and Labrador	0.03	-0.06	0.02	0.00
Nova Scotia	2.50	0.11	-0.38	2.23
Ontario	49.78	0.99	-2.92	47.84
Prince Edward Island	0.24	-0.01	-0.04	0.20
Quebec	12.34	-0.46	-0.42	11.46
Saskatchewan	3.79	0.23	-0.65	3.37
Total	105.70	2.06	-7.76	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Finally, we will consider the geographic distribution of the large negative effect on productivity from the mining and oil and gas extraction industry (Table 15). Unsurprisingly, the effect was concentrated in the provinces with relatively abundant oil, gas, and mineral resources. Most provinces made a negative contribution with the notable exceptions of Newfoundland and Labrador and Nova Scotia. As we have noted earlier, Newfoundland and Labrador's mining and oil and gas extraction sector experienced very strong productivity growth over the period, resulting in a large positive within-sector effect. Alberta and Saskatchewan jointly account for 86 per cent of the negative contribution to MFP growth from the industry.

Table 15: Mining and Oil and Gas Extraction's Contributions to All Province MFP Growth by Province, CSLS Decomposition, Per Cent of the Industry's Total Contribution, 1997-2012

	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total Contribution to MFP Growth
Alberta	61.57	-55.62	61.75	67.71
British Columbia	3.90	-2.52	3.88	5.27
Manitoba	1.08	-0.34	0.80	1.54
New Brunswick	1.00	-0.11	0.31	1.19
Newfoundland and Labrador	-5.49	1.97	-0.68	-4.21
Nova Scotia	0.16	-0.11	-0.07	-0.02
Ontario	6.03	-0.97	1.63	6.69
Prince Edward Island	0.00	0.00	0.00	0.00
Quebec	2.70	-0.37	0.82	3.15
Saskatchewan	14.43	-11.12	15.36	18.67
Total	85.38	-69.19	83.81	100.00

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030.

Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

IV. Conclusion

From 1997 to 2012, multifactor productivity growth in Canada's business sector industries was lacklustre at a rate of 0.76 per cent annually. This paper has presented a series of 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 two major factors contributing to aggregate MFP growth. However, the two decompositions we employ disagree as to which of these sectors generated productivity growth and which hindered it.

The generally 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 below average productivity. The GEAD finds that Alberta and 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 by 80 per cent. 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, but it is straightforward to apply it to multifactor productivity as well. The CSLS decomposition suggests that manufacturing and the finance, insurance, real estate, and leasing industries accounts for the most of the growth in MFP in Canada due to strong productivity growth within these sectors. Three quarters of the MFP growth occurred in Ontario. On the other hand, Saskatchewan and Alberta are found to have lowered aggregate MFP growth because of very large reductions in MFP in the mining and oil and gas extraction industry.

We extend the CSLS and GEAD decomposition methodologies to decompose contributions from each industry and province into contributions associated with labour and contributions associated with capital. The GEAD decomposition suggests that capital and labour both made large contributions to aggregate MFP growth, while the CSLS decomposition suggests that labour accounts for all of the MFP growth, with capital making a small negative contribution. The GEAD decomposition paints a similar picture to the CSLS decomposition if one only considers contributions from within-sector productivity growth, but suggests that capital made a strong positive contribution due because price growth of output was stronger in capital intensive sectors and capital intensive sectors grew more over the period.

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

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Appendix

A. An Alternative Approach to Reallocation Effects

While we will use the CSLS decomposition of labour reallocation in our calculations, we can briefly discuss how the reallocation effects might be further refined to avoid the above criticism. 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.[25] 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.[26] 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)[27], 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:

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[25] 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.

[26] 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.

[27] 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.

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.[28]

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

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

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

[28] 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).

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

where A is the level of multifactor productivity (a Solow residual) and $\bar{s}_{zm}$ is the average (nominal) compensation share of input m.[29] 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:

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

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:

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

can be rewritten as:

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[29] 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).

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

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, $Y_a^t = \alpha_a^t Y_n^t$.[30]

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:

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

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

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

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

[30] 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.

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

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.[31]

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

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

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.

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.

[31] 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.

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:

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

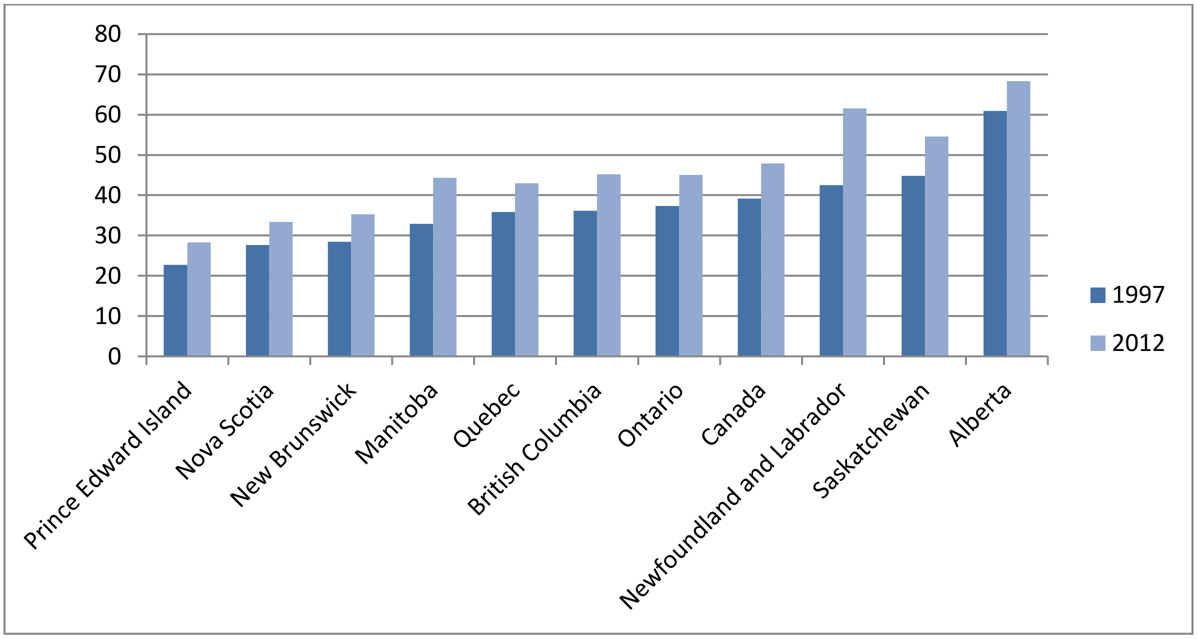
ii. Labour Data

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 2012. Labour productivity is above average in only the three major oil producing provinces. It is lowest in the Maritimes. Ontario, British Columbia, and Quebec are all relatively close to the national average.

Appendix Chart 1: Labour Productivity Levels by Province, Business Sector Industries, Real GDP Per Hour Worked, Chained 2007 Dollars, 1997 and 2012

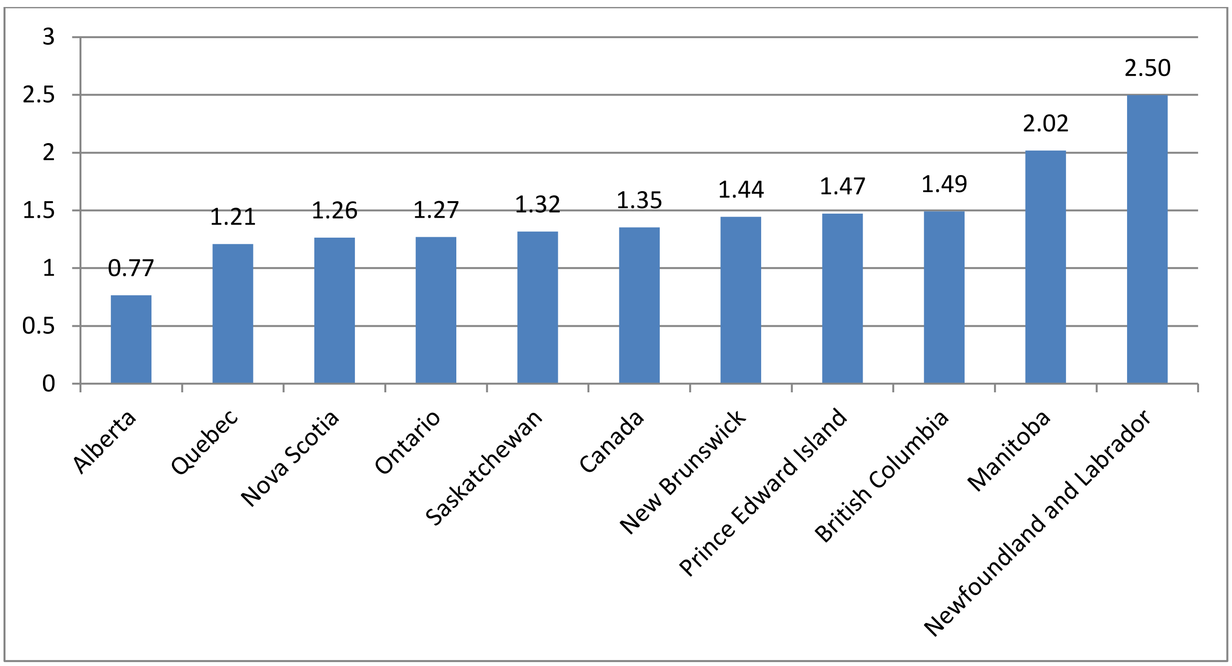


Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

Appendix Chart 2 presents the labour productivity growth rates between 1997 and 2012. Alberta stands out as the province which had the lowest labour productivity growth (0.77 per cent annually), but it still had the highest labour productivity level at the end of the period. Labour productivity growth in most provinces was close to the average (1.35 per cent per year). Two provinces stand out as having above average labour productivity growth: Newfoundland and Labrador (2.5 per cent) and Manitoba (2.0 per cent).

The distribution of hours worked across the provinces (Appendix Chart 3) is very similar to the distribution of the total population. For our purposes, the reallocation of labour input across provinces (Appendix Chart 4) between 1997 and 2012 is more relevant. Alberta's share of hours worked increased by 2.5 percentage points. With the exception of Newfoundland and Labrador,[32] all other provinces experienced declines in their shares of total hours worked over the period. Ontario's hours share experienced the largest decline (0.73 percentage points).

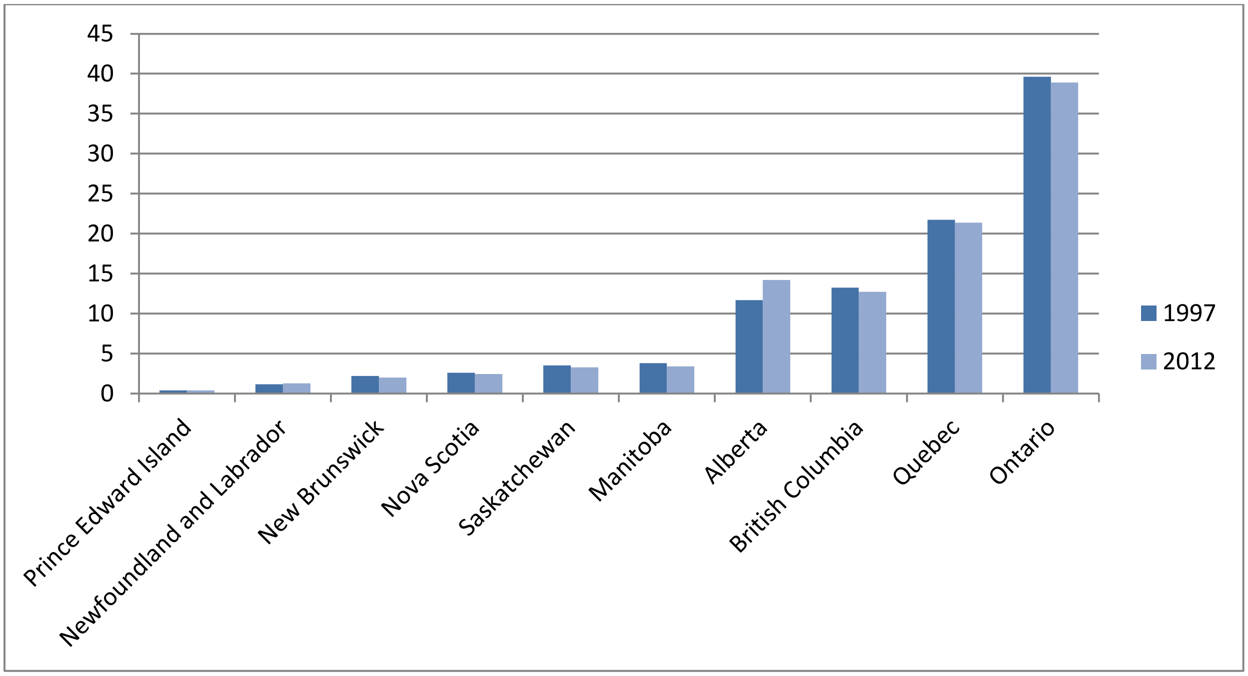
Appendix Chart 2: Labour Productivity Growth by Province, Business Sector Industries, Real GDP Per Hour Worked (Chained 2007 Dollars), Compound Annual Rate of Change, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

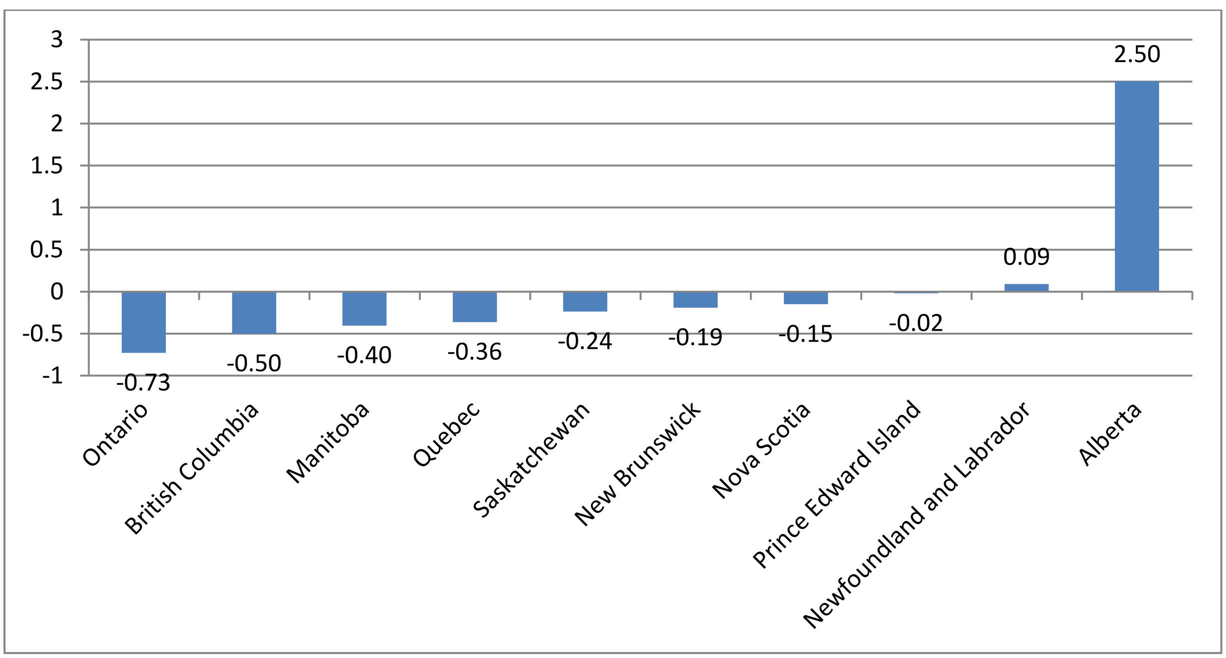
[32] Newfoundland and Labrador's rising share of hours worked is a bit surprising if one is aware that the province's share of Canada's population aged 15+ fell from 1.89 per cent in 1997 to 1.57 per cent in 2012. This can be explained by very strong growth in the province's employment rate from 43.1 per cent in 1997 to 54.3 per cent in 2012 compared to the national improvement from 59.0 per cent in 1997 to 61.7 per cent in 2012 (data from CANSIM Table 287-0087). Average hours worked also increased in Newfoundland and Labrador over the period.

Appendix Chart 3: Distribution of Hours Worked Across the Provinces, Business Sector Industries, Per Cent of All Provinces Total, 1997 and 2012



Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

Appendix Chart 4: Change in Province's Share of Hours Worked in All Provinces, Business Sector Industries, Percentage Points, 1997-2012

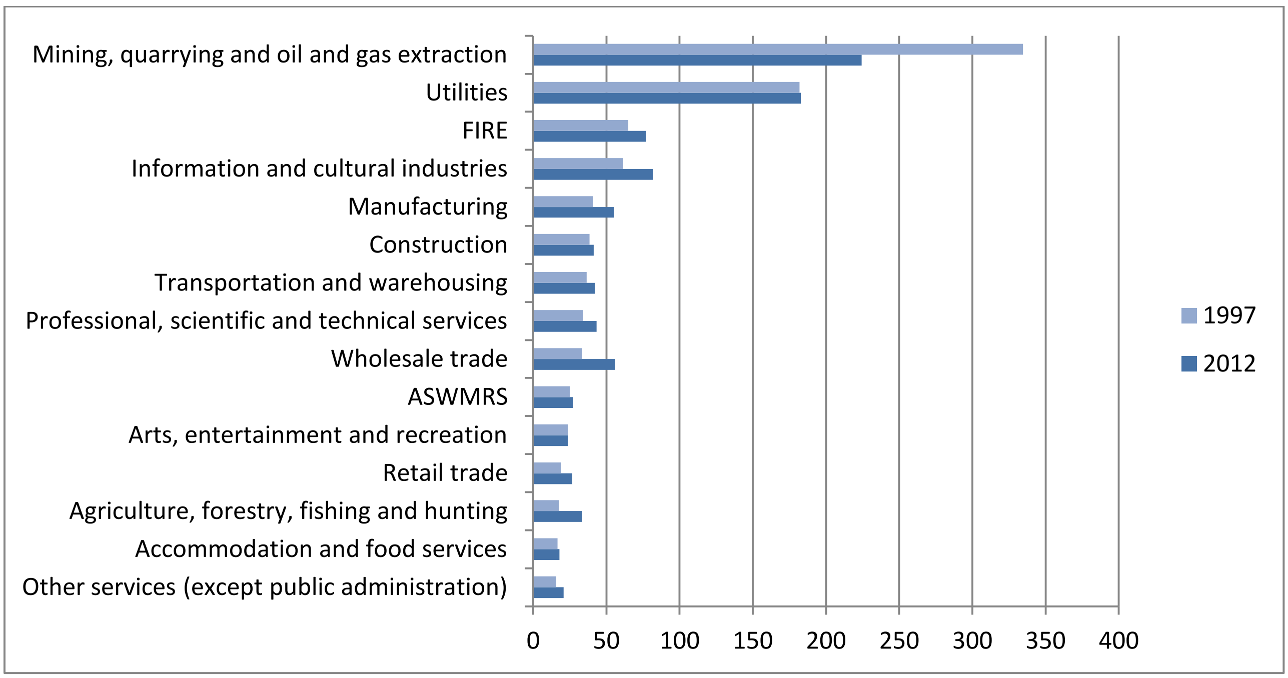


Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

Appendix Chart 5 provides labour productivity levels by industry, clarifying the sources of some of the provincial trends. Labour productivity in oil and gas extraction is extremely high compared to all other industries at $334.6 per hour in 1997 (in chained 2007 dollars). Labour productivity in that industry fell to $224.3 per hour in 2012, but remains far above that of any other industry. It is also worth noting that the labour productivity level of the utilities industry ($182 in both 1997 and 2012) is also far above average.

Mining and oil and gas extraction was the only industry to exhibit a large negative rate of labour productivity growth between 1997 and 2012 (Appendix Chart 6). Labour productivity increased in most industries. The highest growth rates were observed in agriculture, forestry, fishing, and hunting (4.3 per cent annually), wholesale trade (3.5 per cent), and retail trade (2.2 per cent). The reader should also note that manufacturing's labour productivity rose at a rate of 2.0 per cent per year.

Appendix Chart 5: Labour Productivity Levels by Business Sector Industry, All Provinces, Real GDP Per Hour Worked (Chained 2007 Dollars), Compound Annual Rate of Change, 1997 and 2012

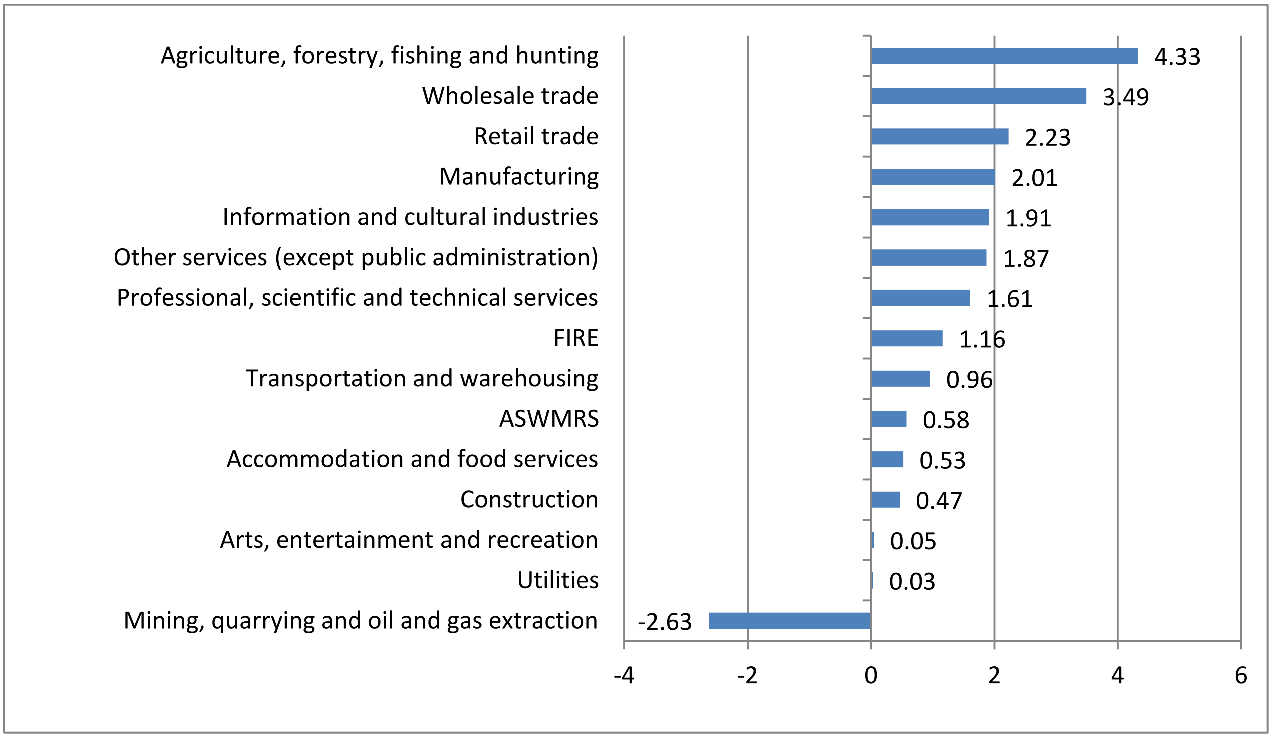


Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

More hours were worked in manufacturing than in any other sector (19.6 per cent of the total) in 1997 (Appendix Chart 7). Other large industries in 1997 included retail trade (12.5 per cent of hours worked), FIRE (9.2 per cent), and construction (8.3 per cent). Labour productivity growth within a sector will have an effect on aggregate labour productivity growth proportional to the size of the sector. Notice that mining and oil and gas extraction had a relatively small share of hours worked in 1997 (1.5 per cent), but it still has a large effect on aggregate labour productivity growth because of its unusually high labour productivity level which fell by more than double the average labour productivity level in the business sector.

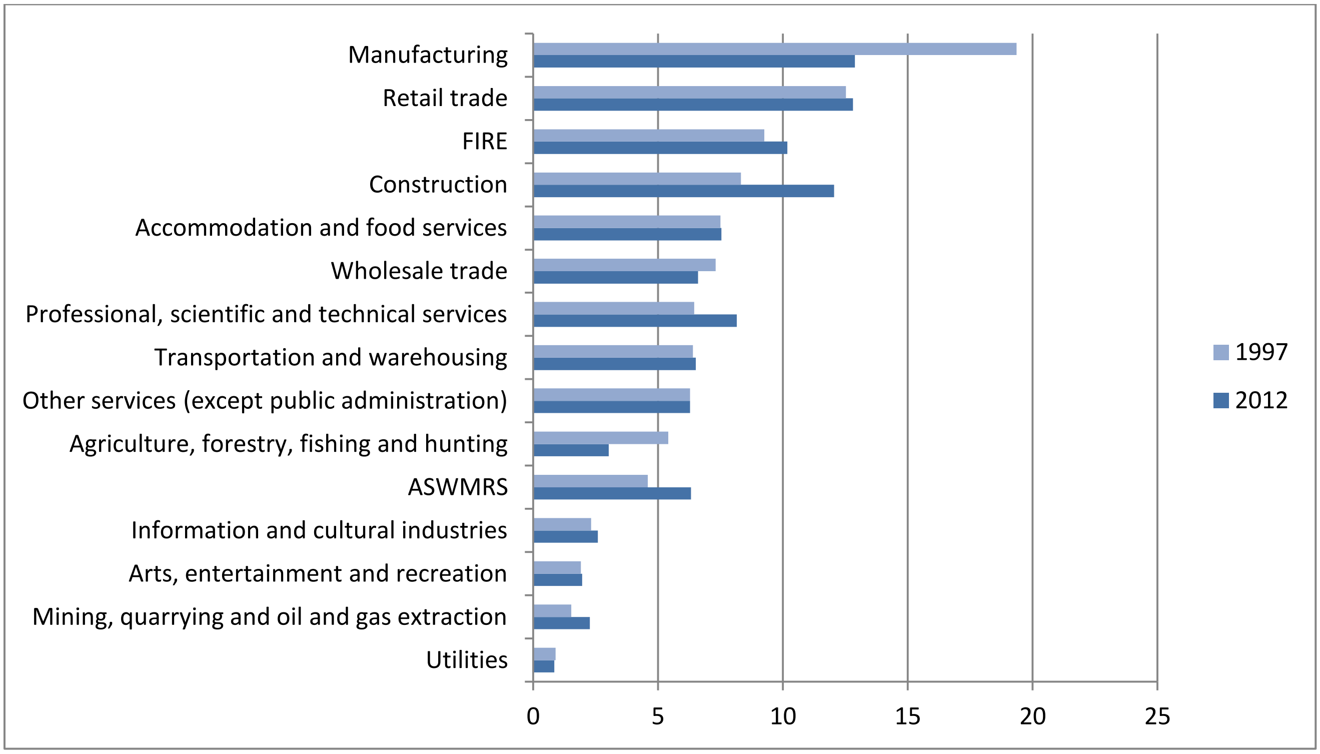
Appendix Chart 6: Labour Productivity Growth by Business Sector Industry, All Provinces, Real GDP Per Hour Worked (Chained 2007 Dollars), Compound Annual Rate of Change, 1997-2012



Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

Appendix Chart 7: Distribution of Hours Worked Across Business Sector Industries, All Provinces, Per Cent of Business Sector Industries Total, 1997 and 2012

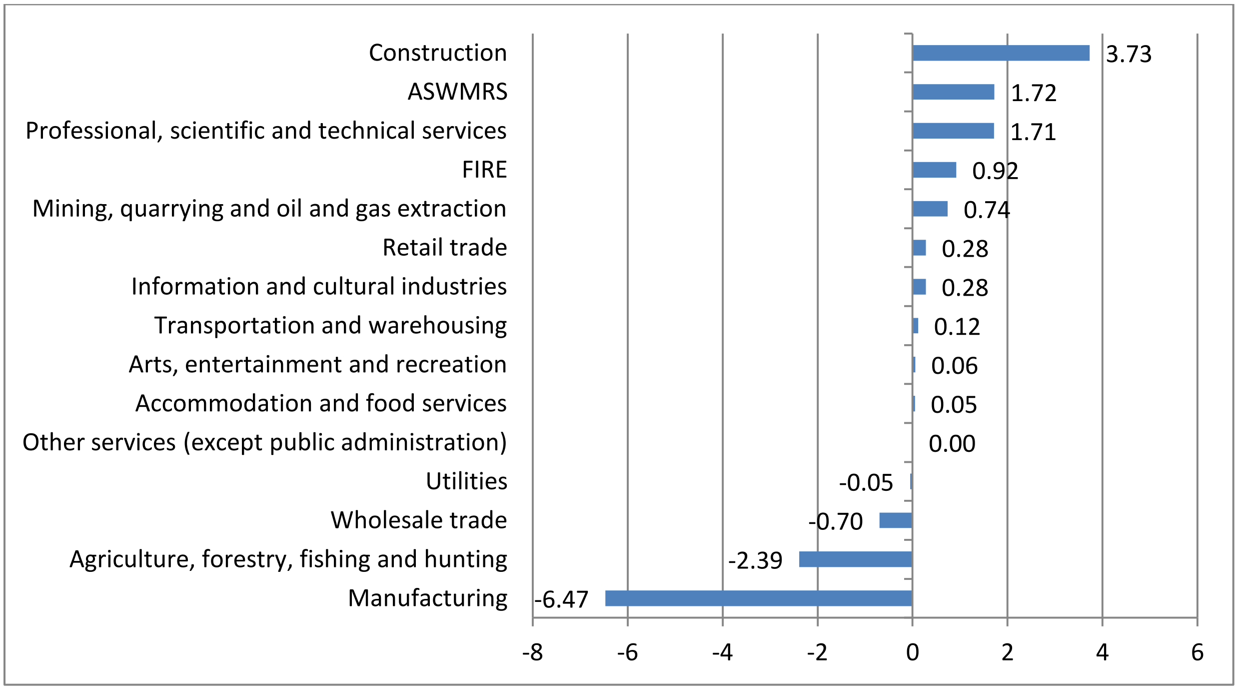


Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

Construction's share of total hours worked increased by 3.7 percentage points between 1997 and 2012 (Appendix Chart 8). ASWMRS and professional, scientific, and technical services also experienced large increases in their labour input shares of 1.7 percentage points each. Manufacturing's share of hours worked plummeted by 6.5 percentage points. Agriculture, forestry, fishing, and hunting lost 2.4 percentage points of total hours worked and wholesale trade lost 0.7 percentage points.

Appendix Chart 8: Change in Industry's Share of Total Hours Worked in Business Sector Industries, All Provinces, Percentage Points, 1997-2012



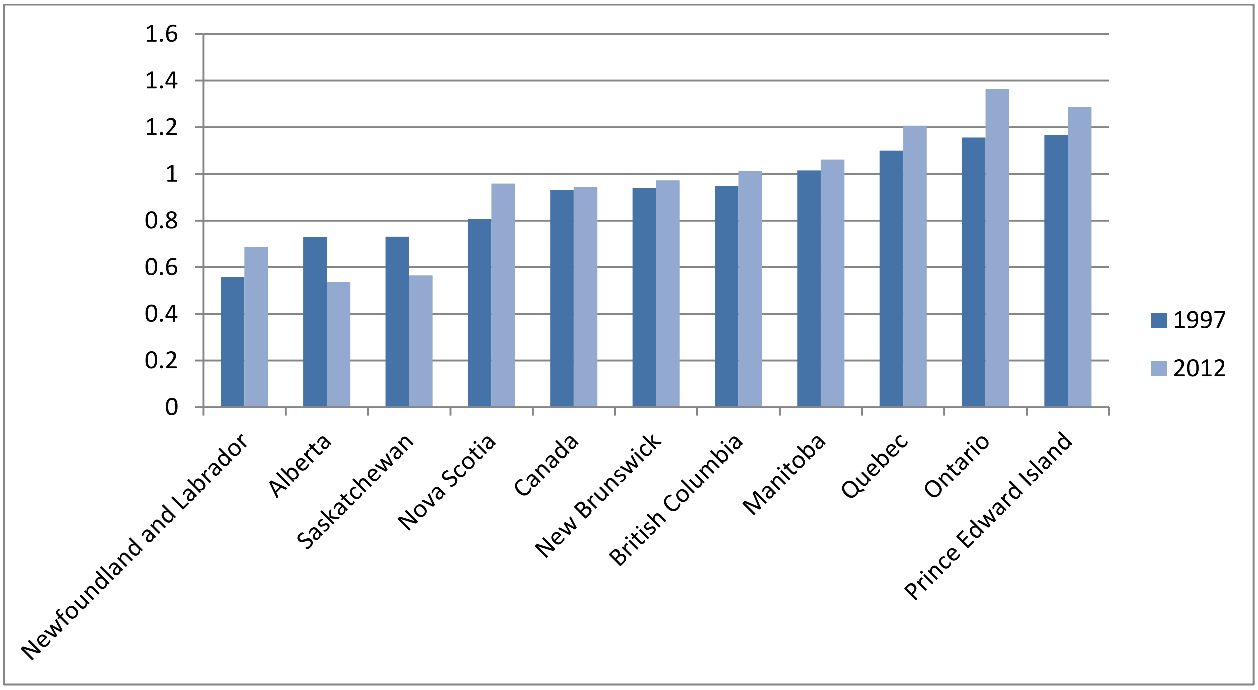
Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 383-0011 and 383-0029

iii. Capital Data

Many of the above trends in labour productivity are well-known, but capital productivity tends to receive much less attention. In 1997, the aggregate capital productivity level was $0.93 of output per dollar of capital stock (chained 2007 dollars) (Appendix Chart 9). Prince Edward Island had the highest capital productivity level in 1997 at $1.17 per dollar of capital stock. Ontario and Quebec also had above average capital productivity at $1.16 and $1.10 per dollar of capital, respectively. The lowest capital productivity levels were in Newfoundland and Labrador, Alberta and Saskatchewan due to the very capital intensive nature of the mining and oil and gas extraction industry.

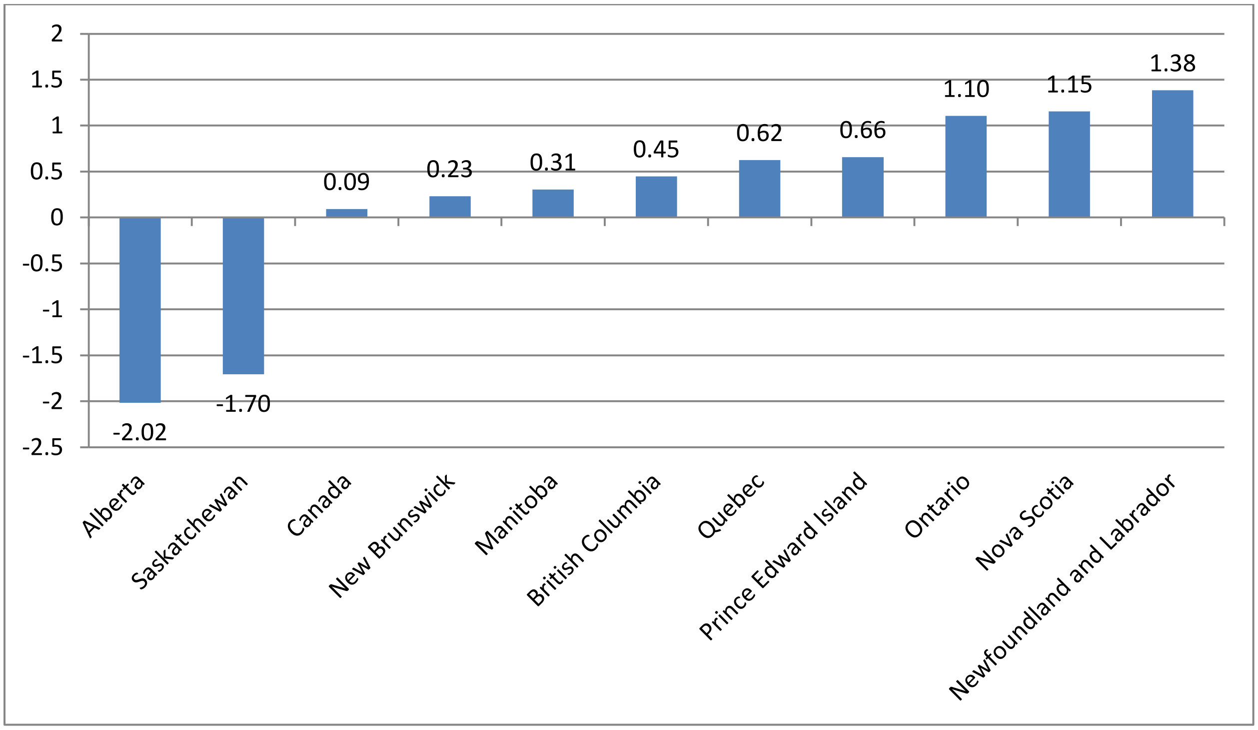
Appendix Chart 9: Capital Productivity Levels by Province, Business Sector Industries, Real GDP Per Hour Worked (Chained 2007 Dollars), Compound Annual Rate of Change, 1997 and 2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

Between 1997 and 2012, capital productivity fell by 2.0 per cent per year in Alberta and by 1.7 per cent per year in Saskatchewan as the oil and gas sector expanded (Appendix Chart 10). On the other hand, Newfoundland and Labrador experienced capital productivity growth of 1.4 per cent per year, the fastest rate among the provinces. Thus, although all three of the major oil-producing provinces have relatively low *levels* of capital productivity, the oil industries of Eastern and Western Canada appear to differ in terms of their capacity for capital productivity *growth*. Meanwhile, capital productivity in Ontario and Quebec -- the centres of manufacturing in Canada -- grew by 1.1 and 0.6 per cent per year, respectively, over the 1997-2012 period. In aggregate across all provinces, capital productivity growth was just 0.1 per cent per year.

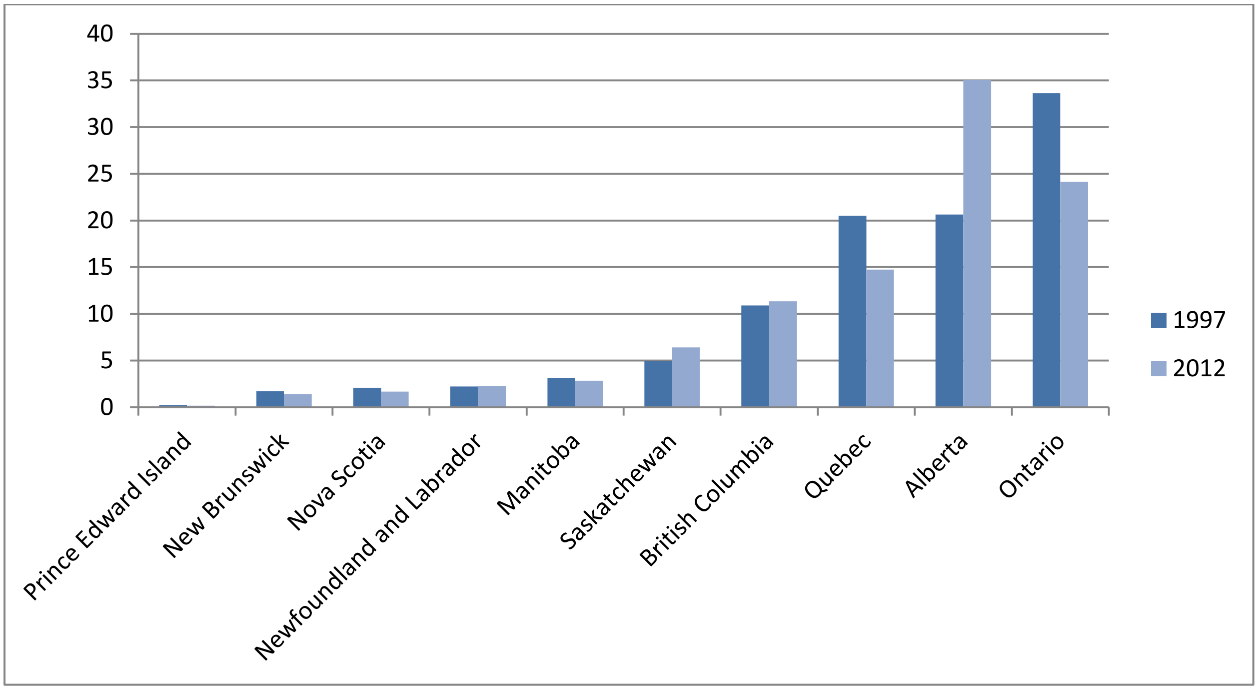
Appendix Chart 10: Capital Productivity Growth by Province, Business Sector Industries, Real GDP Per Hour Worked (Chained 2007 Dollars), Compound Annual Rate of Change, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

The geographic distribution of capital diverges considerably from that of the total population although they are still correlated. Appendix Chart 11 indicates that Ontario had the largest share of the total capital stock in 1997 (33.6 per cent). Alberta had the second largest share (20.6 per cent) followed by Quebec (20.5 per cent). The massive reallocation of capital from Ontario and Quebec to Alberta between 1997 and 2012 is striking (Appendix Chart 12). Alberta's share of the capital stock rose by 14.4 percentage points while Ontario's fell by 9.5 percentage points and Quebec's by 5.8 percentage points. Given the very low capital productivity level in Alberta compared to Ontario and Quebec, this reallocation put downward pressure on aggregate capital productivity and MFP (ignoring changes in relative prices).

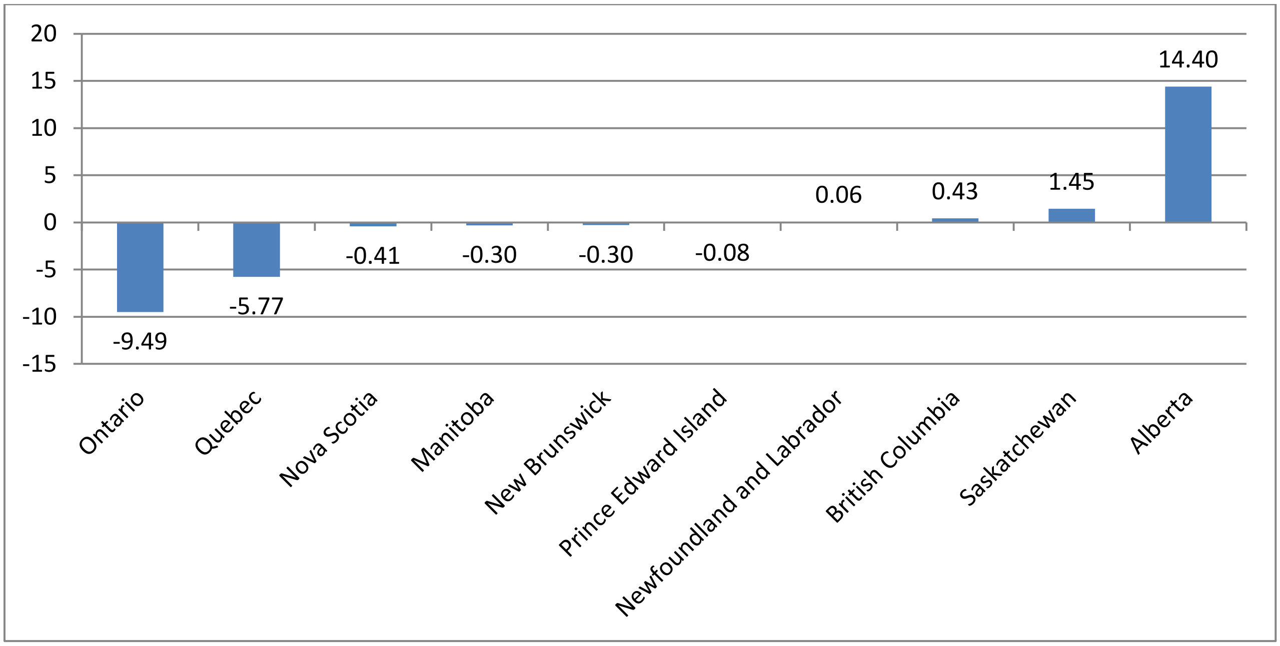
Appendix Chart 11: Distribution of Capital Stock across the Provinces, Business Sector Industries, Per Cent of All Province Total, 1997 and 2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

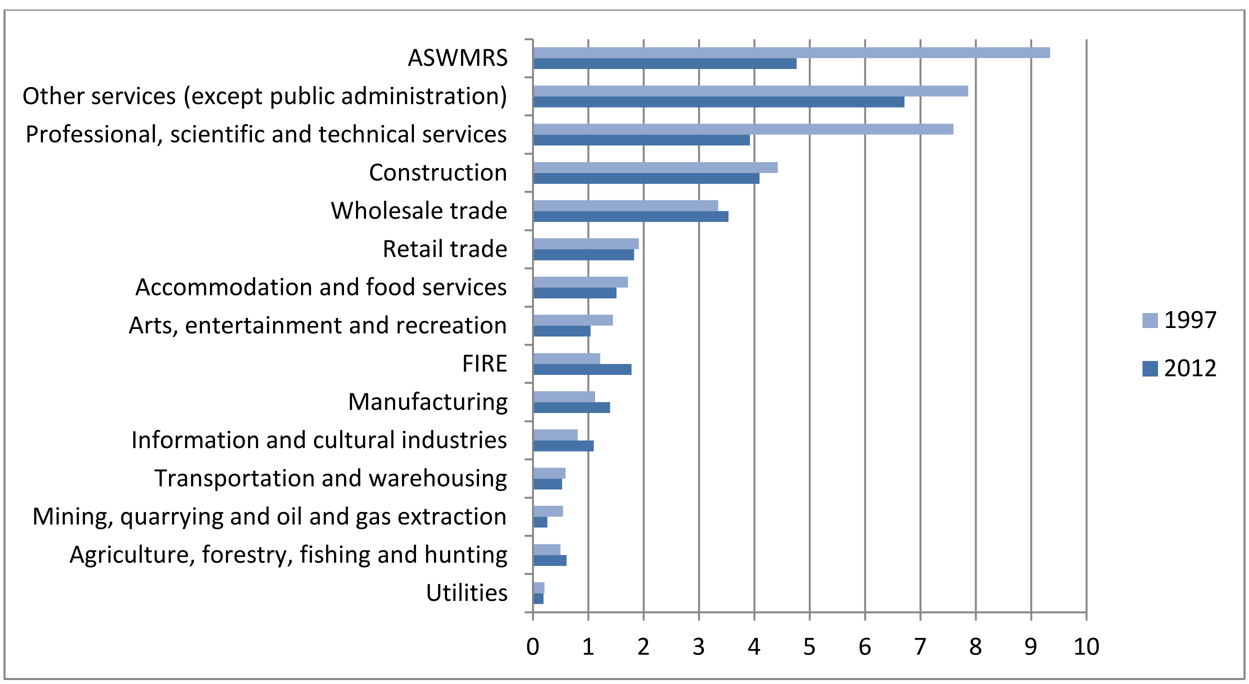
Similar to labour productivity, there is wide variation in capital productivity across industries (Appendix Chart 13). The industries with the lowest levels of capital productivity in 1997 were utilities ($0.21 of output per dollar of capital stock), agriculture, forestry, fishing, and hunting ($0.50 per dollar), and mining and oil and gas extraction ($0.54 per dollar). At the opposite extreme, ASWMRS had a capital productivity of $9.34 per dollar, followed by Other services at $7.86 and professional, scientific, and technical services $7.60. Capital productivity in manufacturing was $1.12.

Appendix Chart 12: Change in Industry's Share of Total Capital Stock in All Provinces, Business Sector Industries, Percentage Points, 1997-2012



Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

Appendix Chart 13: Capital Productivity Levels by Business Sector Industry, Real GDP Per Dollar Capital Stock, Chained 2007 Dollars, 1997 and 2012

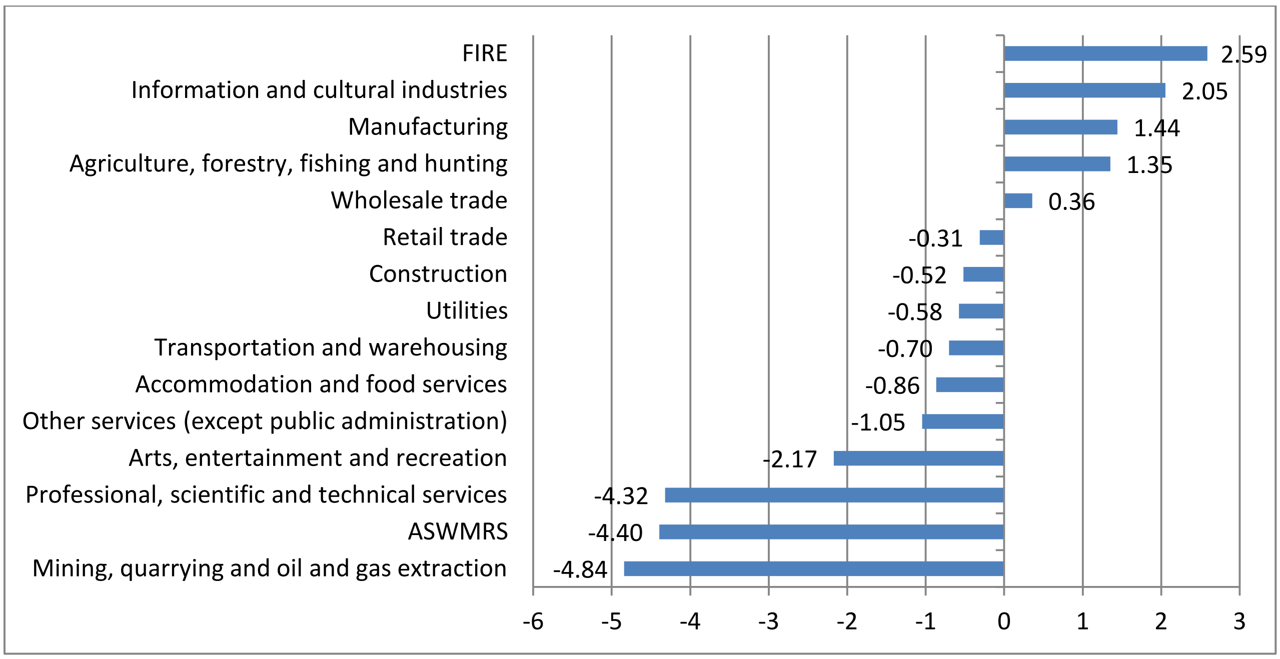


Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

Capital productivity fell within most sectors between 1997 and 2012 (Appendix Chart 14). The largest declines were in mining, quarrying and oil and gas extraction (4.8 per cent per year), ASWMRS (4.4 per cent per year), and professional, scientific and technical services (4.3 per cent per year). The strongest growth was observed in FIRE (2.6 per cent per year), information and cultural industries (2.1 per cent per year), and manufacturing (1.4 per cent per year).

Appendix Chart 14: Capital Productivity Growth by Business Sector Industry, Real GDP Per Dollar Capital Stock (Chained 2007 Dollars), Compound Annual Rate of Change, 1997-2012

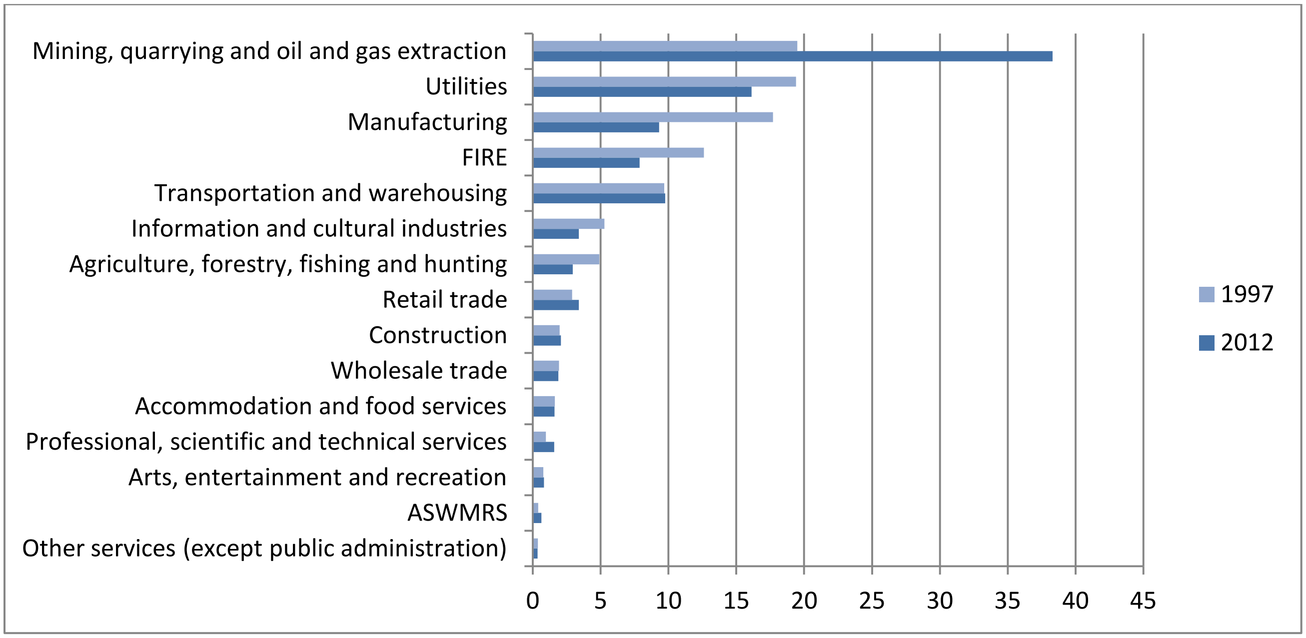


Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

Finally, consider the allocation of capital across industries (Appendix Chart 15). Mining and oil and gas extraction had the largest share of the total capital stock in 1997 at 19.5 per cent. This share rocketed to 38.3 per cent by 2012. Other sectors which had large shares of the total capital stock in 1997 include utilities (19.4 per cent), manufacturing (17.7 per cent), and FIRE (12.6 per cent). All three of those industries experienced large declines in their shares of the total capital stock between 1997 and 2012 (Appendix Chart 16). The largest decline in capital share was in manufacturing, at 8.4 per cent. 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.

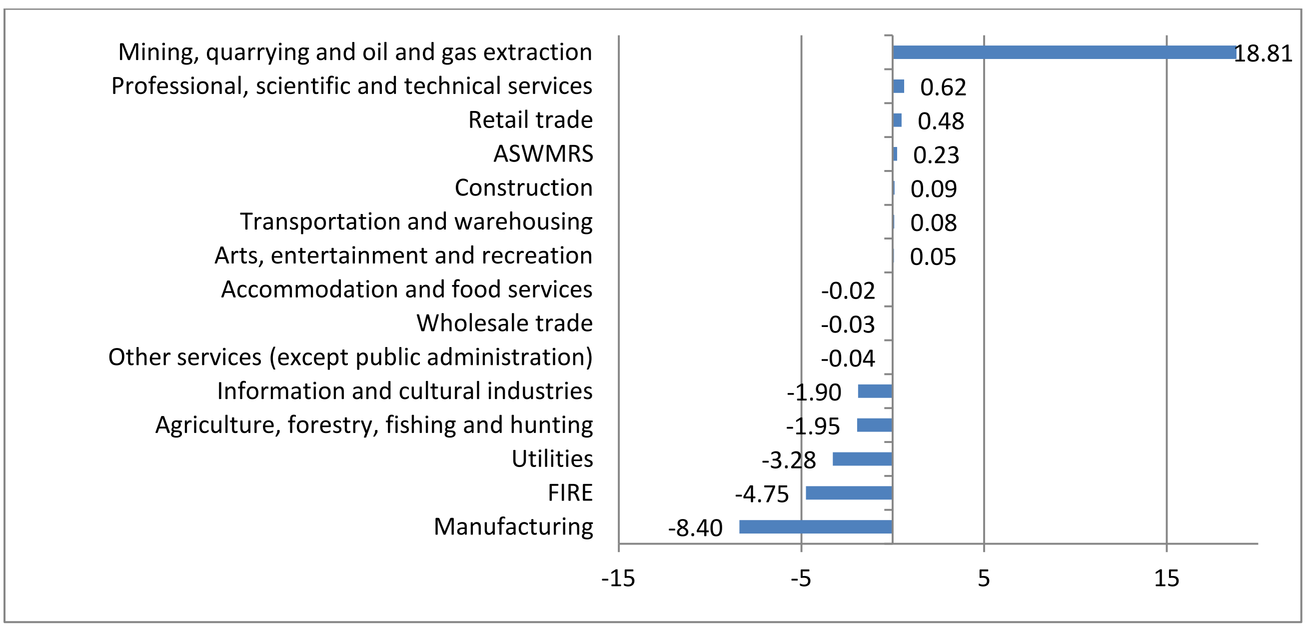
Appendix Chart 15: Distribution of Capital Stock Across Business Sector Industries, All Provinces, Per Cent of Business Sector Industries Total, 1997 and 2012



Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

Appendix Chart 16: Change in Industry's Share of Total Capital Stock in Business Sector Industries, All Provinces, Percentage Points, 1997-2012



Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0011, 383-0029

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 and Appendix Table 2. 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 sector's share of total input costs within the industry

Nearly 98 per cent of the growth in aggregate MFP is due to within-sector productivity growth (Appendix Table 2). Output relative price changes explains 24 per cent of aggregate MFP growth, changes in the distribution of total input costs explain 17 per cent, and changes in the relative importance of capital and labour within-sectors explains 6 per cent (2.55*2). These price and substitution effects are offset by a contribution of -45 per cent from changes in relative input prices. These results are generally quite similar to those for the basic GEAD decomposition which does not break down contributions by input.

Interestingly, aggregate MFP growth is found to be fairly evenly split between the two inputs. Capital accounts for 44 per cent of aggregate MFP growth while labour explains 56 per cent. This is somewhat counterintuitive given that aggregate labour productivity increased while aggregate capital productivity fell. This arises due to reallocation effects, substitution, and changes in relative prices. If we only consider within-sector productivity growth, labour productivity contributed 105 per cent and capital productivity -8 per cent.

Changes in relative output prices had a positive effect with capital (30 per cent of aggregate MFP growth) and a negative effect with labour (-6 per cent). Note that within-industry, output price growth was identical across both inputs. This result may suggest that the industries which experienced the largest relative output price growth were relatively capital intensive in that they use more capital than labour.[33] Relative input price growth also had a much larger negative effect associated with labour (-40 per cent of aggregate MFP growth) than capital (-4 per cent). Generally, this may suggest that the relative price of labour fell compared to that of capital.

Substitution between labour and capital in terms of total input costs within each sector was found to have had a positive effect of 9.5 per cent of aggregate MFP growth for capital and a negative effect of -4.4 per cent for labour. Growth of sectors in terms of share of all-sector total input costs had a positive contribution of 16.1 per cent associated with capital and 1.2 per cent associated with labour, suggesting that the sectors experiencing the greatest increase in their input shares were relatively capital intensive.

In summary, labour and capital made similar contributions to aggregate MFP growth. Labour's contribution was almost entirely due to within-sector labour productivity growth and was negatively affected by input and output price changes. Capital productivity's contribution was mostly the result of rising output prices and reallocation and substitution of inputs.

Notice that the total industry contributions are exactly the same as those of the baseline GEAD, but this decomposition reveals a few interesting details as to where the effects occurred within each sector.

Alberta's strong contribution to aggregate MFP growth was fairly evenly divided between contributions from labour and capital with large output price and reallocation effects for both inputs. The negative contributions from Ontario and Quebec were related to capital rather than labour. Of the -2.17 percentage point contribution from Ontario, -2.64 percentage points were from capital while labour was associated with a positive contribution of 0.47 percentage points.

Examining the contributions by industry, we find that the large negative contribution of manufacturing (-9.56 percentage points) was due to both capital and labour, although capital was somewhat more important (-6.22 percentage points compared to -3.34 percentage points). Notice the importance of the substitution (change in input's share of total input costs of the sector) in the larger contribution from capital.

The large positive contribution from mining and oil and gas extraction (7.67 percentage points) was mostly related to capital (6.28 percentage points) although labour also made a notable positive contribution (1.39 percentage points). In contrast, the other major positive contributor, construction, was driven more by labour (3.26 percentage points) than by capital (1.91 percentage points).

[33] Labour's share of total compensation is much lower in mining and oil and gas extraction than in most other industries.

Appendix Table 1: GEAD of MFP Growth by Province and Business Sector Industry, Percentage Point Contributions, 1997-2012

	Labour						Capital						Total			
	γ	ρ	ω	σ	ϕ	Total	γ	ρ	ω	σ	ϕ	Total	γ	ρ	ω	σ
Total	12.68	-0.73	-4.85	0.15	-0.26	6.71	-0.91	3.67	-0.51	1.94	0.57	5.34	11.77	2.94	-5.36	2.09
Alberta	1.33	2.77	-2.63	4.61	-0.70	4.68	-3.27	4.30	-1.69	4.69	0.73	5.47	-1.94	7.06	-4.33	9.31
British Columbia	1.82	-0.32	-0.14	-0.47	-0.44	0.01	0.20	0.02	-0.28	-0.17	0.48	0.72	2.01	-0.30	-0.42	-0.64
Manitoba	0.51	0.03	-0.15	0.00	-0.17	0.05	0.06	0.08	-0.17	0.01	0.17	0.32	0.57	0.11	-0.32	0.01
New Brunswick	0.24	-0.10	-0.01	-0.17	-0.01	-0.06	-0.02	-0.10	0.26	-0.22	-0.02	-0.12	0.22	-0.19	0.25	-0.39
Newfoundland and Labrador	0.23	0.11	-0.15	0.27	-0.12	0.22	0.57	0.51	-1.61	1.00	0.15	0.78	0.80	0.63	-1.76	1.27
Nova Scotia	0.26	-0.08	-0.07	-0.16	0.03	0.01	0.10	-0.06	0.07	-0.13	-0.03	-0.08	0.36	-0.14	0.00	-0.29
Ontario	5.45	-2.97	-0.55	-3.55	1.04	0.47	2.45	-2.69	2.98	-3.70	-0.84	-2.64	7.90	-5.66	2.43	-7.24
Prince Edward Island	0.03	0.00	0.00	0.00	-0.02	0.00	0.01	0.00	-0.02	-0.01	0.02	0.02	0.04	0.00	-0.02	-0.01
Quebec	2.44	-0.89	-0.70	-1.20	0.61	0.87	0.50	-0.78	1.91	-1.52	-0.61	-1.10	2.94	-1.67	1.22	-2.72
Saskatchewan	0.37	0.72	-0.44	0.81	-0.49	0.46	-1.50	2.39	-1.97	1.99	0.53	1.97	-1.14	3.11	-2.41	2.80
Accommodation and food services	0.18	0.17	-0.16	-0.12	0.08	0.24	-0.08	0.05	0.20	-0.03	-0.09	-0.03	0.09	0.22	0.05	-0.14
ASWMRS	0.22	0.39	-0.27	0.90	-0.06	1.13	-0.74	0.16	0.59	0.37	0.06	0.50	-0.52	0.55	0.32	1.27
Agriculture, forestry, fishing and hunting	0.93	-0.12	-0.18	-0.36	-0.43	-0.59	0.34	-0.01	-0.59	-0.24	0.42	0.33	1.26	-0.12	-0.77	-0.60
Arts, entertainment and recreation	0.00	0.13	-0.09	0.00	0.05	0.13	-0.13	0.06	0.16	0.00	-0.05	-0.01	-0.13	0.19	0.07	0.00
Construction	0.43	1.36	-0.60	2.94	-0.44	3.26	-0.06	0.53	-0.65	1.20	0.45	1.91	0.37	1.89	-1.25	4.14
FIRE	1.31	-0.67	-0.04	-0.15	0.26	0.97	3.62	-0.84	-1.45	-0.25	-0.26	0.55	4.94	-1.51	-1.49	-0.41
Information and cultural industries	0.58	-0.43	0.00	-0.03	0.10	0.31	0.81	-0.54	0.13	-0.02	-0.10	0.18	1.39	-0.97	0.13	-0.05
Manufacturing	3.66	-3.14	-1.20	-6.99	2.16	-3.34	2.09	-2.44	4.03	-5.45	-2.22	-6.22	5.75	-5.58	2.83	-12.44
Mining and oil and gas extraction	-1.40	3.26	-0.67	2.63	-1.22	1.39	-5.07	7.55	-5.39	6.56	1.31	6.28	-6.47	10.81	-6.06	9.19
Other private services	0.67	0.16	-0.22	0.34	-0.33	0.29	-0.04	0.03	-0.78	0.07	0.57	0.42	0.63	0.19	-1.01	0.41
Professional, scientific and technical services	1.31	0.17	-0.56	1.67	-0.30	2.00	-1.20	0.06	0.95	0.53	0.31	0.97	0.11	0.23	0.38	2.21
Retail trade	1.75	-0.72	-0.32	0.07	-0.10	0.58	-0.07	-0.24	0.42	0.05	0.10	0.35	1.68	-0.97	0.10	0.12
Transportation and warehousing	0.53	-0.24	0.15	-0.43	0.02	0.05	-0.25	-0.12	0.64	-0.20	-0.01	0.06	0.29	-0.36	0.79	-0.63
Utilities	-0.01	0.00	-0.22	-0.30	0.35	0.17	-0.28	0.03	0.93	-0.70	-0.35	-0.72	-0.29	0.03	0.72	-1.00
Wholesale trade	2.51	-1.04	-0.48	-0.03	-0.41	0.13	0.16	-0.61	0.30	0.05	0.43	0.76	2.67	-1.65	-0.18	0.02

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030. Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Appendix Table 2: GEAD of MFP Growth by Province and Business Sector Industry, Per Cent of Total MFP Growth, 1997-2012

	Labour						Capital						Total			
	γ	ρ	ω	σ	ϕ	Total	γ	ρ	ω	σ	ϕ	Total	γ	ρ	ω	σ
Total	105.15	-6.03	-40.27	1.21	-2.19	55.68	-7.51	30.45	-4.23	16.12	4.74	44.32	97.64	24.42	-44.50	17.33
Alberta	11.04	22.94	-21.85	38.26	-5.79	38.81	-27.16	35.63	-14.03	38.92	6.02	45.41	-16.12	58.58	-35.88	77.18
British Columbia	15.07	-2.65	-1.14	-3.92	-3.65	0.05	1.65	0.14	-2.34	-1.39	3.95	5.96	16.71	-2.51	-3.48	-5.31
Manitoba	4.25	0.22	-1.28	-0.03	-1.39	0.38	0.48	0.66	-1.37	0.09	1.41	2.68	4.73	0.88	-2.65	0.07
New Brunswick	1.97	-0.80	-0.09	-1.44	-0.08	-0.52	-0.15	-0.80	2.15	-1.81	-0.18	-0.96	1.82	-1.59	2.06	-3.25
Newfoundland and Labrador	1.91	0.95	-1.28	2.28	-1.00	1.85	4.72	4.26	-13.32	8.26	1.26	6.45	6.63	5.21	-14.60	10.54
Nova Scotia	2.16	-0.68	-0.59	-1.33	0.26	0.08	0.85	-0.49	0.60	-1.08	-0.27	-0.66	3.01	-1.17	0.01	-2.40
Ontario	45.23	-24.63	-4.59	-29.40	8.66	3.94	20.30	-22.29	24.73	-30.65	-7.00	-21.90	65.53	-46.91	20.14	-60.06
Prince Edward Island	0.27	0.03	0.01	-0.01	-0.15	-0.01	0.09	-0.02	-0.20	-0.09	0.18	0.15	0.36	0.01	-0.19	-0.10
Quebec	20.21	-7.36	-5.78	-9.92	5.06	7.25	4.18	-6.46	15.87	-12.63	-5.05	-9.13	24.39	-13.82	10.09	-22.55
Saskatchewan	3.04	5.95	-3.68	6.73	-4.10	3.85	-12.47	19.80	-16.32	16.49	4.41	16.33	-9.43	25.75	-19.99	23.21
Accommodation and food services	1.48	1.40	-1.30	-0.97	0.70	2.00	-0.69	0.44	1.68	-0.21	-0.72	-0.23	0.78	1.84	0.37	-1.18
ASWMRS	1.86	3.23	-2.24	7.48	-0.50	9.33	-6.17	1.34	4.93	3.09	0.48	4.15	-4.31	4.56	2.69	10.57
Agriculture, forestry, fishing and hunting	7.70	-0.96	-1.50	-2.99	-3.57	-4.90	2.78	-0.07	-4.92	-1.96	3.47	2.77	10.48	-1.03	-6.42	-4.96
Arts, entertainment and recreation	0.02	1.07	-0.74	-0.01	0.38	1.11	-1.10	0.47	1.36	0.00	-0.40	-0.08	-1.08	1.54	0.62	-0.02
Construction	3.58	11.29	-4.98	24.43	-3.63	27.07	-0.53	4.38	-5.40	9.93	3.74	15.86	3.04	15.67	-10.38	34.36
FIRE	10.89	-5.56	-0.29	-1.28	2.15	8.06	30.04	-6.96	-12.06	-2.10	-2.17	4.59	40.93	-12.51	-12.35	-3.38
Information and cultural industries	4.80	-3.60	-0.02	-0.27	0.82	2.54	6.71	-4.47	1.08	-0.19	-0.83	1.48	11.51	-8.07	1.06	-0.46
Manufacturing	30.38	-26.04	-9.94	-57.94	17.90	-27.74	17.34	-20.24	33.41	-45.25	-18.42	-51.57	47.72	-46.29	23.48	-103.19
Mining and oil and gas extraction	-11.58	27.01	-5.55	21.80	-10.09	11.50	-42.06	62.64	-44.72	54.42	10.90	52.09	-53.64	89.65	-50.26	76.22
Other private services	5.55	1.36	-1.86	2.85	-2.73	2.43	-0.32	0.25	-6.50	0.59	4.74	3.50	5.23	1.60	-8.35	3.44
Professional, scientific and technical services	10.87	1.40	-4.66	13.89	-2.46	16.59	-9.97	0.53	7.85	4.41	2.60	8.02	0.90	1.93	3.19	18.30
Retail trade	14.48	-6.00	-2.65	0.57	-0.80	4.81	-0.55	-2.02	3.47	0.42	0.80	2.93	13.93	-8.01	0.82	1.00
Transportation and warehousing	4.43	-1.99	1.28	-3.60	0.14	0.39	-2.04	-1.00	5.31	-1.63	-0.07	0.50	2.39	-2.99	6.59	-5.23
Utilities	-0.10	0.01	-1.80	-2.52	2.92	1.43	-2.30	0.23	7.75	-5.80	-2.93	-6.00	-2.41	0.24	5.94	-8.32
Wholesale trade	20.79	-8.65	-4.01	-0.21	-3.43	1.06	1.34	-5.07	2.52	0.39	3.55	6.29	22.14	-13.72	-1.49	0.18

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030. Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services

Appendix Table 3 and Appendix Table 4 present comparable results from the CSLS decomposition. Keep in mind that this decomposition was performed by (approximately) decomposing aggregate MFP growth into contributions of aggregate capital productivity and labour productivity and then decomposing these two components using the CSLS partial productivity decompositions. Since aggregated capital productivity growth was negative, this resulted in a negative total contribution from capital. The CSLS decomposition concludes that all of the aggregate MFP growth was due to labour while the GEAD decomposition had found that both capital and labour made large contributions. Price changes and substitution, which do not appear in the CSLS decomposition, were major sources of the contribution of capital productivity in the GEAD decomposition.

The total contribution of labour is found to have been 131 per cent of the total in the CSLS decomposition. Of this, 118 per cent is from the within-sector labour productivity effect. The reallocation level effect contributed 54.1 per cent, but 40.9 per cent of this was offset by the reallocation growth effect. The within-sector effect of capital was found to be positive at 5.3 per cent of the total. The reallocation level effect was comparable to that from labour at 48.5 per cent, but there was a very large reallocation growth effect which lowered MFP growth by 84.8 per cent. This is linked to industries with large declines in MFP increasing their capital share (mining and oil and gas extraction and professional, scientific, and technical services) and those with strong capital productivity growth losing capital share (FIRE, manufacturing, and agriculture, forestry, fishing, and hunting).

Unlike the GEAD, total sector contributions do not exactly match those from the basic CSLS decomposition above, although they are highly correlated. The CSLS decomposition suggests that Alberta's negative contribution to MFP growth of -4.01 percentage points was due entirely to capital (-5.96 percentage points). Labour in Alberta made a positive contribution of 1.95 percentage points. About three quarters of the large positive contribution from Ontario was also related to labour productivity.

Within industry, we find that the large negative contribution from mining and oil and gas extraction (-10.9 percentage points) was mostly associated with capital (-9.7 percentage points) rather than labour (-1.2 percentage points). Within the three industries which made the largest positive contributions (FIRE, manufacturing, and wholesale trade), both capital and labour made positive contributions. However, the contribution of labour was larger in all three sectors, especially in manufacturing and wholesale trade.

Appendix Table 3: CSLS Decomposition of MFP Growth by Province and Business Sector Industry, Percentage Point Contributions, 1997-2012

	Contribution of Labour Productivity				Contribution of Capital Productivity				Total Contribution to MFP			
	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total
Total	14.20	6.52	-4.93	15.79	0.64	5.85	-10.23	-3.74	14.84	12.37	-15.15	12.06
Alberta	-0.24	4.54	-2.35	1.95	-2.87	0.13	-3.22	-5.96	-3.11	4.67	-5.57	-4.01
British Columbia	2.34	0.23	-0.23	2.34	0.42	0.61	-1.61	-0.58	2.76	0.84	-1.84	1.75
Manitoba	0.74	0.20	-0.09	0.85	0.07	0.13	-0.14	0.05	0.81	0.32	-0.23	0.90
New Brunswick	0.29	0.02	-0.02	0.29	-0.01	0.18	-0.13	0.04	0.28	0.20	-0.15	0.33
Newfoundland and Labrador	0.40	0.11	0.09	0.60	0.22	0.10	-0.11	0.21	0.62	0.21	-0.02	0.82
Nova Scotia	0.37	0.00	-0.06	0.31	0.12	0.13	-0.19	0.06	0.49	0.13	-0.25	0.37
Ontario	6.70	0.31	-1.01	6.00	2.61	2.71	-3.16	2.15	9.31	3.01	-4.17	8.15
Prince Edward Island	0.04	0.01	0.00	0.05	0.02	0.03	-0.03	0.02	0.06	0.04	-0.04	0.07
Quebec	3.35	0.02	-0.49	2.89	0.48	1.61	-1.01	1.08	3.83	1.63	-1.49	3.97
Saskatchewan	0.21	1.08	-0.77	0.52	-0.41	0.22	-0.62	-0.82	-0.20	1.30	-1.39	-0.29
Accommodation and food services	0.19	-0.01	-0.01	0.17	-0.14	0.07	-0.12	-0.19	0.04	0.07	-0.13	-0.02
ASWMRS	0.20	-0.47	-0.22	-0.48	-0.75	2.08	-1.24	0.08	-0.55	1.61	-1.46	-0.40
Agriculture, forestry, fishing and hunting	1.63	1.00	-0.33	2.29	0.38	0.39	-0.18	0.59	2.01	1.39	-0.52	2.88
Arts, entertainment and recreation	0.01	-0.01	-0.02	-0.02	-0.16	0.16	-0.16	-0.16	-0.15	0.15	-0.17	-0.18
Construction	0.40	0.04	-0.39	0.04	-0.13	0.96	-0.06	0.77	0.27	1.00	-0.45	0.82
Finance, insurance, real estate, rental and leasing	2.18	0.50	0.03	2.71	4.04	-0.61	-1.36	2.07	6.23	-0.11	-1.34	4.78
Information and cultural industries	0.93	0.17	-0.02	1.08	0.75	0.04	-0.15	0.64	1.68	0.21	-0.17	1.72
Manufacturing	5.23	-0.16	-0.72	4.35	2.84	-0.90	-1.57	0.37	8.07	-1.06	-2.29	4.73
Mining and oil and gas extraction	-3.99	5.67	-2.87	-1.19	-4.17	-2.89	-2.68	-9.74	-8.16	2.78	-5.55	-10.92
Other private services	0.60	0.01	0.00	0.61	-0.09	0.22	-0.12	0.02	0.51	0.23	-0.11	0.62
Professional, scientific and technical services	1.14	-0.14	-0.03	0.97	-1.51	3.94	-2.18	0.25	-0.37	3.80	-2.21	1.22
Retail trade	1.78	-0.10	0.01	1.69	-0.14	0.32	-0.08	0.10	1.64	0.22	-0.07	1.79
Transportation and warehousing	0.68	0.06	-0.06	0.68	-0.32	0.03	-0.06	-0.35	0.36	0.09	-0.12	0.33
Utilities	0.14	-0.15	-0.13	-0.14	-0.20	1.60	-0.08	1.32	-0.06	1.45	-0.22	1.18
Wholesale trade	3.09	0.11	-0.17	3.03	0.23	0.43	-0.18	0.48	3.32	0.54	-0.35	3.51

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030. Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation services Note: Contributions have been scaled so that the contributions sum to the calculated aggregate MFP growth rate. The original sum was 10.2.

Appendix Table 4: CSLS Decomposition of MFP Growth by Province and Business Sector Industry, Per Cent of Total MFP Growth, 1997-2012

	Contribution of Labour Productivity				Contribution of Capital Productivity				Total Contribution to MFP			
	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total	Within-Sector Effect	Reallocation Level Effect	Reallocation Growth Effect	Total
Total	117.76	54.07	-40.85	130.99	5.34	48.51	-84.83	-30.99	123.10	102.58	-125.68	100.00
Alberta	-2.01	37.67	-19.51	16.15	-23.77	1.07	-26.71	-49.40	-25.77	38.74	-46.21	-33.25
British Columbia	19.40	1.88	-1.91	19.37	3.46	5.06	-13.35	-4.83	22.86	6.95	-15.26	14.54
Manitoba	6.13	1.64	-0.75	7.02	0.56	1.05	-1.18	0.44	6.69	2.69	-1.93	7.46
New Brunswick	2.39	0.16	-0.19	2.37	-0.10	1.52	-1.08	0.35	2.29	1.68	-1.26	2.71
Newfoundland and Labrador	3.31	0.95	0.76	5.02	1.85	0.82	-0.90	1.78	5.16	1.77	-0.13	6.79
Nova Scotia	3.04	0.02	-0.46	2.60	1.01	1.08	-1.59	0.50	4.04	1.10	-2.05	3.09
Ontario	55.58	2.55	-8.35	49.78	21.62	22.44	-26.24	17.83	77.21	24.99	-34.59	67.60
Prince Edward Island	0.34	0.09	-0.02	0.42	0.15	0.27	-0.28	0.15	0.49	0.37	-0.29	0.57
Quebec	27.82	0.15	-4.03	23.94	3.97	13.36	-8.36	8.97	31.79	13.51	-12.39	32.91
Saskatchewan	1.77	8.97	-6.41	4.33	-3.43	1.81	-5.15	-6.77	-1.67	10.79	-11.55	-2.43
Accommodation and food services	1.56	-0.06	-0.08	1.42	-1.20	0.61	-1.02	-1.61	0.35	0.55	-1.10	-0.19
ASWMRS	1.69	-3.89	-1.81	-4.01	-6.26	17.24	-10.31	0.67	-4.57	13.35	-12.12	-3.34
Agriculture, forestry, fishing and hunting	13.50	8.27	-2.75	19.02	3.16	3.24	-1.52	4.88	16.67	11.51	-4.28	23.90
Arts, entertainment and recreation	0.04	-0.09	-0.14	-0.18	-1.32	1.32	-1.30	-1.30	-1.28	1.23	-1.44	-1.48
Construction	3.30	0.31	-3.25	0.36	-1.05	7.98	-0.52	6.41	2.25	8.29	-3.76	6.77
Finance, insurance, real estate, rental and leasing	18.10	4.13	0.24	22.47	33.55	-5.07	-11.31	17.16	51.65	-0.94	-11.08	39.63
Information and cultural industries	7.70	1.41	-0.14	8.97	6.23	0.37	-1.27	5.32	13.92	1.77	-1.41	14.29
Manufacturing	43.41	-1.36	-5.95	36.09	23.57	-7.43	-13.03	3.10	66.98	-8.79	-18.98	39.20
Mining and oil and gas extraction	-33.08	47.03	-23.78	-9.84	-34.56	-23.97	-22.22	-80.75	-67.64	23.06	-46.00	-90.59
Other private services	4.94	0.07	0.03	5.03	-0.74	1.84	-0.98	0.13	4.20	1.91	-0.95	5.16
Professional, scientific and technical services	9.43	-1.12	-0.25	8.06	-12.53	32.64	-18.04	2.07	-3.09	31.52	-18.29	10.14
Retail trade	14.76	-0.81	0.07	14.01	-1.13	2.64	-0.65	0.86	13.63	1.82	-0.58	14.87
Transportation and warehousing	5.61	0.50	-0.48	5.63	-2.62	0.23	-0.50	-2.89	2.99	0.74	-0.99	2.74
Utilities	1.16	-1.23	-1.11	-1.18	-1.63	13.29	-0.69	10.97	-0.48	12.06	-1.80	9.79
Wholesale trade	25.65	0.92	-1.44	25.14	1.87	3.58	-1.46	3.99	27.53	4.50	-2.90	29.13

Source: CSLS Calculations using data from CANSIM Tables 031-0005, 383-0031, 379-0025 and 379-0030. Note: FIRE stands for Finance, Insurance, and Real Estate; ASWMRS stands for administrative and support, waste management and remediation service.