

# Sectoral Contributions to Labour Productivity Growth in Canada: Does the Choice of Decomposition Formula Matter?

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## ABSTRACT

Using three decomposition formulas (TRAD, CSLS, and GEAD), this article estimates sectoral contributions to business sector labour productivity growth in Canada during the 2000-2010 period. Although at the aggregate economy level there was substantial agreement among the three formulas, contribution estimates varied widely at the sectoral level. In particular, there were significant differences in the estimated contributions of construction, manufacturing, and mining and oil and gas extraction. Ultimately, these differences reflect the fact that traditional decomposition formulas (TRAD and CSLS) and the GEAD formula measure different economic phenomena. Instead of seeing estimates constructed by the GEAD and traditional formulas as “competing” narratives, the article concludes it is more useful to see them as providing complementing stories about the role of different sectors in driving aggregate labour productivity growth.

## RÉSUMÉ

Utilisant trois formules de décomposition (TRAD, CSLS et GEAD), cet article estime la contribution des secteurs à la croissance de la productivité du travail dans le secteur des entreprises au Canada au cours de la période 2000-2010. Bien qu'au niveau agrégé de l'économie, les trois formules aient donné des estimations largement semblables, les estimations varient considérablement à l'échelle des secteurs. Il existe en particulier de grandes différences entre les estimations pour les secteurs de la construction, de la fabrication, et de l'exploitation minière et de l'extraction du pétrole et du gaz. En fin de compte, ces différences viennent de ce que les formules de décomposition traditionnelles (TRAD et CSLS) et la formule GEAD mesurent des phénomènes économiques différents. Plutôt que de considérer les estimations données par la formule GEAD et les formules traditionnelles comme “concurrentes”, l'article conclut qu'il est plus utile de considérer comme complémentaire ce qu'elles nous disent sur le rôle des différents secteurs dans la croissance de la productivité agrégée du travail.

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AN IMPORTANT PART of productivity analysis is the estimation of sectoral contributions to aggregate labour productivity growth. Several decomposition formulas have been developed for this purpose. Unfortunately, different decomposition formulas frequently yield significantly different results. The objective of this article is to compare estimates produced by three such formulas in the case of labour productivity growth in the Canadian business sector during the 2000-2010 period.

In the past 20 years, statistical agencies around the world have increasingly favoured chained indexes in place of fixed-base indexes when calculating real output. The advantages of chained indexes over their fixed-base counterparts are well established in the economics literature (see, for instance, Whelan (2002)), but a few points are worth highlighting here. Generally speaking, real output estimates in constant prices – i.e. calculated using fixed-base indexes – use relative prices from an arbitrarily chosen base period as the basis for comparison with all the other periods; on the other hand, real output estimates in chained prices – i.e. calculated using chained indexes – take into account the fact that relative prices are constantly changing. The growth rate of real output in constant prices depends on the choice of the base year, becoming increasingly “unbalanced” as one moves further and further away from it. This does not happen with real output in chained prices, since relative prices are updated every period. Thus, in general, chained indexes produce better quality estimates of real output.

A disadvantage of using chained indexes, however, is that real output estimates cease to be additive. When real output is computed using fixed-base Laspeyres quantity and Paasche price indexes,<sup>2</sup> aggregate real output is exactly equal

to the sum of its individual components. This is not true when chained indexes are used. In this case, aggregate real output is equal to the sum of its individual components *only* for the chosen reference year (when real output is also equal to nominal output). The difference between the two increases as one moves away from the reference year.

Even though statistical agencies have updated their methods, productivity analysts still often use techniques that *assume* real output is additive. This is particularly true when it comes to decomposition formulas used to find sectoral or regional contributions to aggregate labour productivity growth. Labour productivity estimates are constructed using real output and labour input estimates. Since official real output estimates are now calculated mainly with chained indexes, labour productivity growth decomposition formulas that assume real output in constant prices generate sectoral or regional contributions that do not sum up *exactly* to aggregate labour productivity growth.

Tang and Wang (2004) addressed this issue with their Generalized Exactly Additive Decomposition (GEAD) formula. By taking into account changes in relative prices, the GEAD formula is able to generate sectoral contribution estimates that are perfectly additive irrespective of how real output is calculated. Despite this clear advantage over other decomposition formulas, the GEAD formula is still not widely used by productivity analysts, possibly due to some of its results being perceived as counterintuitive.

Dumagan (2012) compared the GEAD formula to a traditional decomposition formula (TRAD) that assumed real output in constant prices. He concluded that the GEAD formula produced superior estimates from both an

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2 A Laspeyres formula uses base period prices (or quantities, in the case of a price index) as weights, whereas a Paasche formula uses current period prices (or quantities, in the case of a price index) as weights. The Fisher formula is a geometric average of the Laspeyres and Paasche formulas. For a discussion on these and other index number formulas, as well as on many topics central to index number theory, see Diewert (1993).

empirical and an analytical point of view. The purpose of this article is to expand Dumagan's investigation on how estimates produced by the GEAD formula compare to those produced by traditional labour productivity growth decomposition formulas. In order to do so, a third decomposition formula is added to the mix and sectoral contribution estimates for all three formulas are analysed in the case of labour productivity growth in the Canadian business sector during the 2000-2010 period.

This article is organized as follows. Section two presents the TRAD decomposition formula, a variation of that formula developed by the Centre for the Study of Living Standards (CSLS), and the GEAD formula. Section three compares the sectoral contributions calculated by the three formulas for the Canadian business sector during the 2000-2010 period. Section four concludes.

## Decomposing Aggregate Labour Productivity Growth

This section describes three formulas commonly used to calculate sectoral contributions to aggregate labour productivity growth. The first decomposition formula is the TRAD formula, which, according to Dumagan (2012), can be traced back to Denison (1962). It assumes that real output is measured in constant prices – more specifically, using fixed-base Laspeyres quantity and Paasche price indexes – so that aggregate real output corresponds to the sum of sectoral real output. A second decomposition formula, referred to here as the CSLS decomposition, was developed by the Centre for the Study of Living Standards (CSLS) and is used in several of its articles and reports, including Sharpe (2009), Sharpe (2010), and Sharpe and Thomson (2010). The CSLS formula is essentially a variation of the TRAD formula. It also

assumes real output in constant prices, but differs significantly from the TRAD formula in the way it accounts for the contribution of each sector to aggregate productivity growth. Finally, the last formula was developed by Tang and Wang (2004) (see also Diewert (2008) for an alternative formulation) and is perfectly additive regardless of how real output is measured. Following Dumagan (2012), the Tang and Wang decomposition is referred to here as the Generalized Exactly Additive Decomposition (GEAD) formula.<sup>3</sup>

This section is divided into three parts, the first of which presents the TRAD formula, while the second and third parts describe the CSLS and GEAD formula, respectively. This section draws from Dumagan (2012), especially regarding the choice of notation of the TRAD and GEAD formulas.

### TRAD Decomposition

The TRAD decomposition formula is widely used to measure the contribution of different sectors to aggregate productivity growth (see, for example, Dekle and Vandembroucke (2006), IMF (2006), and Usui (2011)). The underlying assumption of this formula is that real output is calculated in constant prices using fixed-base Laspeyres quantity and Paasche price indexes at both the aggregate and sectoral levels. When this happens, the sum of sectoral real output (net of intermediate inputs, i.e. value added)  $x_t^{*i}$  is equal to the economy's real output  $x_t^*$ , i.e.  $x_t^* = \sum_i x_t^{*i}$ , where the superscript  $i=1, 2, \dots, N$  denotes the sector and the subscript  $t=1, 2, \dots, T$  denotes the time period. Defining labour productivity as output per unit of labour input, aggregate labour productivity is  $z_t^* = \frac{x_t^*}{L_t}$  and sectoral productivity is  $z_t^{*i} = \frac{x_t^{*i}}{L_t^i}$  where  $L_t$  and  $L_t^i$  represent labour input used in

3 The reader should bear in mind that there are many other labour productivity decompositions that are not discussed or used in this article. See, for instance, Nordhaus (2001); Reinsdorf, Diewert and Ehemann (2002), Diewert (2008), and Reinsdorf and Yuskavage (2010)

the aggregate economy and in sector  $i$  (respectively) such that  $L_t = \sum_i L_t^i$ . In this case, since real output is additive:

$$Z_t^* = \frac{X_t^*}{L_t} = \frac{\sum_i X_t^{*i}}{L_t} = \frac{\sum_i Z_t^{*i} L_t^i}{L_t} = \sum_i Z_t^{*i} l_t^i \quad (1)$$

where  $l_t^i = \frac{L_t^i}{L_t}$ .

Thus, aggregate labour productivity  $Z_t^*$  is equal to the weighted sum of sectoral labour productivity  $Z_t^{*i}$  across all  $i$ 's, where the weights  $l_t^i$  are each sector's labour input shares. Sectoral contribution to aggregate labour productivity growth can be computed by looking at productivity changes ( $G_t^*$ ) between two periods of time:

$$G_t^* = \frac{Z_t^* - Z_{t-1}^*}{Z_{t-1}^*} = \frac{\sum_i (Z_t^{*i} l_t^i - Z_{t-1}^{*i} l_{t-1}^i)}{Z_{t-1}^*} \quad (2)$$

With some algebraic manipulations, the above formula becomes:<sup>4</sup>

$$G_t^* = \sum_i \left[ \frac{X_{t-1}^{*i}}{X_{t-1}^*} G_t^{*i} + \frac{Z_{t-1}^{*i}}{Z_{t-1}^*} \Delta l_t^i + \frac{Z_{t-1}^{*i}}{Z_{t-1}^*} \Delta l_t^i G_t^{*i} \right] \quad (3)$$

where  $G_t^{*i} = \frac{Z_t^{*i} - Z_{t-1}^{*i}}{Z_{t-1}^{*i}}$ .

Equation (3) is the TRAD decomposition formula. According to this formula, sectoral contributions to aggregate productivity growth can be broken down into three effects. The first term of equation (3) represents the *within-sector effect (WSE)*.<sup>5</sup> As the name implies, it measures the contribution to aggregate productivity growth due *solely* to productivity increases experienced by individual sectors. If sectoral labour shares remain unchanged over time ( $\Delta l_t^i = 0$ ), the second and third terms of equation (3) equal zero and the contribution of each sector collapses to the first term, which is the sectoral labour productivity growth weighted by the sector's share in aggregate *real* output ( $\frac{X_{t-1}^{*i}}{X_{t-1}^*}$ ).

The other two terms of equation (3) represent two different sectoral reallocation effects. The second term of equation (3) captures the *reallocation level effect (RLE)*.<sup>6</sup> As Denison (1962) realized, aggregate labour productivity can increase even when sectoral labour productivity remains constant, as long as labour moves from sectors with below average labour productivity levels towards sectors with above average labour productivity levels. In the TRAD decomposition, this effect is positive when  $\Delta l_t^i > 0$ . The ratio between the sector's labour productivity level and the aggregate labour productivity level scales the magnitude of the effect, either increasing it (when  $\frac{Z_{t-1}^{*i}}{Z_{t-1}^*} > 1$ ) or decreasing it (when  $\frac{Z_{t-1}^{*i}}{Z_{t-1}^*} < 1$ ).<sup>7</sup>

The third term is the *reallocation growth effect (RGE)*. It captures a phenomenon similar to Baumol's cost disease (Baumol (1967) and Baumol, Blackman, and Wolff (1985)) – that is, the propensity of labour to move towards sectors where labour productivity is stagnant or declining ( $G_t^{*i} \leq 0$ ). In the TRAD decomposition, this effect will be positive either when labour has moved towards a sector with positive labour productivity growth ( $\Delta l_t^i > 0$  and  $G_t^{*i} > 0$ ) or when labour has moved away from a sector with negative labour productivity growth ( $\Delta l_t^i < 0$  and  $G_t^{*i} < 0$ ). The magnitude of the reallocation growth effect depends not only on  $\Delta l_t^i$  and  $G_t^{*i}$  but also on the ratio between the sector's labour productivity level and the aggregate labour productivity level ( $\frac{Z_{t-1}^{*i}}{Z_{t-1}^*}$ ).

4 For a detailed derivation of the TRAD formula, see Dumagan (2012).

5 Tang and Wang (2004) call this effect the “pure productivity growth effect”, while Dumagan (2012) labels it the “within-sector productivity growth effect”.

6 Tang and Wang (2004) name this effect the “relative size change effect”, noting that it was an “analog of the Denison effect in Nordhaus (2002)” (p.427). Dumagan (2012), in turn, calls this effect the “static structural reallocation effect”.

7 Tang and Wang (2004) simply label this effect as the “interaction term”, while recognizing that it is similar to the Baumol effect in Nordhaus (2002). Dumagan (2012) refers to this effect as the “dynamic structural reallocation effect”.

### CSLS Decomposition

Like the TRAD formula, the CSLS decomposition formula also assumes real output in constant prices calculated using fixed-base Laspeyres quantity and Paasche price indexes, so that sectoral real output sums up to aggregate real output. Starting from equation (1), the *absolute* change in labour productivity between two periods of time is:

$$\Delta Z_t^* = Z_t^* - Z_{t-1}^* = \sum_i (Z_t^{*i} l_t^i - Z_{t-1}^{*i} l_{t-1}^i) \quad (4)$$

With some algebraic manipulations, equation (4) becomes:

$$\Delta Z_t^* = \sum_i \Delta Z_t^{*i} l_{t-1}^i + \sum_i Z_{t-1}^{*i} \Delta l_t^i + \sum_i \Delta Z_t^{*i} \Delta l_t^i \quad (5)$$

Subtracting  $\sum_i Z_{t-1}^{*i} \Delta l_t^i$  and  $\sum_i \Delta Z_t^{*i} \Delta l_t^i$  from equation (5), it becomes:<sup>8</sup>

$$\Delta Z_t^* = \sum_i \Delta Z_t^{*i} l_{t-1}^i + \sum_i (Z_{t-1}^{*i} - Z_t^{*i}) \Delta l_t^i + \sum_i (\Delta Z_t^{*i} - \Delta Z_t^{*i}) \Delta l_t^i \quad (6)$$

Equation (6) is the CSLS decomposition formula. Note that, while the TRAD decomposition stated the contribution of individual sectors in terms of percentage points (relative to the per cent growth in aggregate labour productivity), the CSLS formula looks at absolute changes, i.e. increases in constant dollars per unit of labour. The CSLS formula can be easily modified so that sectoral contributions are stated in percentage points; one needs only divide both sides of equation (6) by  $Z_{t-1}^*$ :

$$G_t^* = \frac{Z_t^* - Z_{t-1}^*}{Z_{t-1}^*} = \frac{\sum_i \Delta Z_t^{*i} l_{t-1}^i}{Z_{t-1}^*} + \frac{\sum_i (Z_{t-1}^{*i} - Z_t^{*i}) \Delta l_t^i}{Z_{t-1}^*} + \frac{\sum_i (\Delta Z_t^{*i} - \Delta Z_t^{*i}) \Delta l_t^i}{Z_{t-1}^*} \quad (7)$$

Analogous to the TRAD decomposition, the first term of the CSLS decomposition formula accounts for the WSE, while the two other terms represent the RLE and the RGE, respectively. Although the CSLS formula appears to specify the WSE differently – with sectoral labour shares ( $l_t^i$ ) instead of real output shares ( $\frac{X_t^{*i}}{X_t^*}$ ) used as weights – the two formulas actually have the same WSE. Recalling that

$G_t^{*i} = \frac{Z_t^{*i} - Z_{t-1}^{*i}}{Z_{t-1}^{*i}}$ , the first term of equation (7) can be rewritten as

$$\begin{aligned} \sum_i \frac{\Delta Z_t^{*i} l_{t-1}^i}{Z_{t-1}^*} &= \sum_i \frac{Z_{t-1}^{*i} l_{t-1}^i \Delta Z_t^{*i}}{Z_{t-1}^{*i} Z_{t-1}^*} = \sum_i \left( \frac{X_{t-1}^{*i} L_{t-1}^i}{L_{t-1} X_{t-1}^*} \right) G_t^{*i} = \\ &= \sum_i \left( \frac{X_{t-1}^{*i}}{X_{t-1}^*} \right) G_t^{*i} \end{aligned} \quad (8)$$

which corresponds to the TRAD's WSE.

The crucial difference between the two formulas lies in how the RLE and RGE are specified and interpreted. Much like in the TRAD decomposition, the CSLS's RLE captures aggregate labour productivity changes caused by labour input shifts to sectors with above- or below-average labour productivity levels. In the CSLS decomposition, this effect is positive either when a sector with above-average labour productivity level ( $Z_t^{*i} > Z_t^*$ ) experiences an increase in its labour input share ( $l_t^i > l_{t-1}^i$ ) or when a sector with below-average labour productivity level ( $Z_t^{*i} < Z_t^*$ ) experiences a reduction in its labour input share ( $l_t^i < l_{t-1}^i$ ). In both the TRAD and CSLS formulas, the magnitude of the RLE is a function of  $\Delta l_t^i$ . In the case of the TRAD formula, however, the effect depends on the *ratio* between the sectoral labour productivity level and the aggregate labour productivity level, while in the CSLS formula it depends on the *absolute difference* between the two.

The third term of the CSLS decomposition formula represents the RGE, which measures the impact of shifts of labour input to sectors with above- or below-average labour productivity growth. This effect is positive either when  $\Delta l_t^i > 0$  and  $\Delta Z_t^{*i} - \Delta Z_t^* > 0$  or when  $\Delta l_t^i < 0$  and  $\Delta Z_t^{*i} - \Delta Z_t^* < 0$ . Both the TRAD's and the CSLS's RGE are a function of  $\Delta l_t^i$ . The difference between the two is reflected, once again, by the fact that the TRAD's RGE

8 As Sharpe (2010) notes, because  $\sum_i \Delta l_t^i = 0$ , the terms  $Z_{t-1}^{*i} \Delta l_t^i$  and  $\Delta Z_t^{*i} \Delta l_t^i$  both sum to zero when aggregated across all sectors.

depends on the ratio between a sector's labour productivity level and the aggregate labour productivity level, whereas the CSLS's RGE is a function of the difference between sectoral labour productivity growth and aggregate labour productivity growth.

### GEAD Decomposition

The TRAD and the CSLS decompositions share a common assumption: that real output is measured in constant prices using fixed base Laspeyres quantity and Paasche price indexes. This guarantees that real aggregate output is equal to the sum of real sectoral output, which leads to equation (1). The Generalized Exactly Additive Decomposition (GEAD) formula has a different starting point. Noting that:

- 1 Aggregate nominal output ( $Y_t$ ) is always additive across sectors ( $Y_t = \sum_i Y_t^i$ , where  $Y_t^i$  represents nominal output of sector  $i$ );
- 2 By definition,  $Y_t = P_t X_t$  and  $Y_t^i = P_t^i X_t^i$  where  $X_t$  and  $X_t^i$  are aggregate and sectoral real output (respectively) and  $P_t$  and  $P_t^i$  are their corresponding price indexes;

then  $Y_t = \sum_i Y_t^i = \sum_i P_t^i X_t^i$ . Defining relative prices ( $\rho_t^i$ ) as the ratio between prices in sector  $i$  and economy-wide prices so that  $\rho_t^i = \frac{P_t^i}{P_t}$ , it can be noted that the relationship between aggregate labour productivity ( $Z_t = \frac{X_t}{L_t}$ ) and sectoral labour productivity ( $Z_t^i = \frac{X_t^i}{L_t^i}$ ) is:

$$Z_t = \frac{X_t}{L_t} = \frac{Y_t}{P_t L_t} = \frac{\sum_i Y_t^i}{P_t L_t} = \frac{\sum_i P_t^i X_t^i}{P_t L_t} = \sum_i \frac{P_t^i L_t^i X_t^i}{P_t L_t L_t^i} = \sum_i \rho_t^i l_t^i z_t^i \quad (9)$$

While equation (1) holds only when output is calculated using fixed base Laspeyres quantity and Paasche price indexes, equation (9) is true regardless of the index number formula used to calculate real output, because  $Y_t = P_t X_t$  and

$Y_t^i = P_t^i X_t^i$  always hold. In particular, equation (9) is true when chained index number formulas are used to measure real output, in which case the additivity of real output does not hold ( $X_t \neq \sum_i X_t^i$ ).

Plugging equation (9) into equation (2) and performing some algebraic manipulations, the expression becomes:<sup>9</sup>

$$G_t = \sum_i \left[ \frac{Y_{t-1}^i}{Y_{t-1}} G_t^i + \frac{Z_{t-1}^i}{Z_{t-1}} (\rho_{t,t-1}^i l_{t-1}^i - \rho_{t-1,t-1}^i l_{t-1}^i) + \frac{Z_{t-1}^i}{Z_{t-1}} (\rho_{t,t}^i l_t^i - \rho_{t-1,t-1}^i l_{t-1}^i) G_t^i \right] \quad (10)$$

where  $G_t$  and  $G_t^i$  are defined analogously to  $G_t^*$  and  $G_t^{*i}$ , with the only difference that now there is no restriction on how real output is computed (which is why the \* is dropped). Equation (10) is the GEAD formula. The similarities – as well as the differences – between equation (10) and equation (3) are immediately noticeable. Much like the TRAD and CSLS decompositions, the GEAD breaks down sectoral contribution into three effects: WSE, RLE, and RGE. The first term of the GEAD represents the WSE. Notice that, while in the TRAD formula the WSE was defined as sectoral labour productivity growth weighted by the sector's *real* output share ( $\frac{X_t^i}{X_t}$ ), in the GEAD sectoral growth is weighted by the sector's *nominal* output share ( $\frac{Y_t^i}{Y_t}$ ).

Regarding the reallocation effects, the GEAD's RLE and RGE do not depend only on how sectoral labour input shares changed over time (as was the case in the TRAD decomposition), but also on relative price movements. Thus, a decline in a sector's labour input share can be offset by an increase in the sector's relative prices. In the GEAD formula, a sector will have a positive RLE when  $\rho_{t,t}^i l_t^i > \rho_{t-1,t-1}^i l_{t-1}^i$ . The RGE will be positive either when  $\rho_{t,t}^i l_t^i > \rho_{t-1,t-1}^i l_{t-1}^i$  and  $G_t^i > 0$  or when  $\rho_{t,t}^i l_t^i < \rho_{t-1,t-1}^i l_{t-1}^i$  and  $G_t^i < 0$ . If there are no movements in relative prices ( $\rho_t^i = 1$ , for all  $t$ ), then the GEAD

9 For a detailed derivation of the GEAD formula, see Tang and Wang (2004), Dumagan (2012), or De Avillez (2012).

formula becomes equal to the TRAD formula.<sup>10</sup>

### **Sectoral Contributions to Business Sector Labour Productivity Growth in Canada, 2000-2010**

This section looks at how different sectors contributed to aggregate labour productivity growth in Canada during the 2000-2010 period according to the TRAD, CSLS, and GEAD decomposition formulas. The section is divided into four parts. The first part provides a brief overview of the data used in this article. The second part describes nominal output, real output, prices, labour input, and labour productivity trends observed in Canada during the 2000-2010 period for both the business sector as a whole and two-digit NAICS sectors. The third part analyses sectoral contribution estimates to aggregate labour productivity growth in the Canadian business sector during the 2000-2010 period. Six sets of estimates are presented. The fourth part discusses which of the three formulas produces “better” estimates.

#### **Data**

Statistics Canada constructs productivity estimates for the Canadian business sector, two-digit NAICS sectors, and three-digit NAICS subsectors. These estimates span a variable period of time, depending on which program they belong to – estimates from the multifactor productivity program currently go all the way back to 1961 and up to 2011 (CANSIM Table 383-0021), while estimates from the labour productivity program span the 1997-2011 period (CANSIM Table 383-0011). Both sets of pro-

ductivity estimates use real GDP in chained 2002 dollars.

Since Statistics Canada constructs real GDP estimates in both constant 2002 dollars and chained 2002 dollars, an option would have been to use Statistics Canada's official productivity numbers and calculate a new set of productivity estimates using real GDP in constant 2002 dollars. Doing so, however, could create additional problems. In particular, there is no guarantee that data adjustments made by Statistics Canada would have been replicable, causing our labour productivity estimates in constant prices to not be perfectly comparable to the official Statistics Canada estimates in chained prices. In order to circumvent this problem, two sets of labour productivity estimates – one in chained 2002 dollars and the other in constant 2002 dollars – were constructed by the author using Statistics Canada data on nominal GDP, real GDP, and hours worked. These estimates span the 2000-2010 period and refer to the Canadian business sector as a whole and two-digit NAICS sectors. Details on how these estimates were constructed can be found in De Avillez (2012).

### **Output, Prices, Labour Input, and Labour Productivity Trends in Canada, 2000-2010**

Nominal GDP in the Canadian business sector increased at an average annual rate of 4.10 per cent during the 2000-2010 period (Table 1). Nominal GDP growth was particularly strong in mining and oil and gas extraction (8.88 per cent per year) and construction (8.22 per cent per year). Due to this above-average growth, the nominal GDP of the two sectors as a share of business sector GDP increased substantially – in

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10 Diewert (2008) notes the difficulty in interpreting the GEAD's RLE and RGE as actual reallocation effects, since the effects of changes in labour shares are mixed with the effects of changes in relative prices. Thus, he proposes an alternative formulation of the GEAD formula, where the two reallocation effects are replaced by a labour input effect and a price effect. Although Diewert's formulation of the GEAD breaks down sectoral contributions into terms that have a more straightforward interpretation, the overall sectoral contributions estimated by his formula will be exactly the same as those estimated by the original GEAD formula.

**Table 1****Nominal GDP in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010**

	Nominal GDP, 2000 (\$ millions)	Nominal GDP, 2010 (\$ millions)	Ave. Annual Growth (%)	Nominal GDP Shares, 2000 (%)	Nominal GDP Shares, 2010 (%)
	$Y_{2000}^i$	$Y_{2010}^i$		$\frac{Y_{2000}^i}{Y_{2000}}$	$\frac{Y_{2010}^i}{Y_{2010}}$
Business sector industries	769,682	1,141,075	4.10	100.0	100.0
Agriculture, forestry, fishing and hunting	22,137	24,996	1.60	2.9	2.2
Mining and oil and gas extraction	60,906	110,904	8.88	7.9	9.7
Utilities	26,242	33,811	2.63	3.4	3.0
Construction	49,648	107,125	8.22	6.5	9.4
Manufacturing	187,462	164,007	-1.22	24.4	14.4
Wholesale trade	50,931	80,680	4.78	6.6	7.1
Retail trade	51,311	86,503	5.39	6.7	7.6
Transportation and warehousing	43,896	67,064	4.38	5.7	5.9
Information and cultural industries	32,150	53,228	5.18	4.2	4.7
FIRE	108,272	180,127	5.23	14.1	15.8
Professional, scientific and technical services	43,566	76,907	5.87	5.7	6.7
ASWMRS	20,367	37,712	6.44	2.6	3.3
Arts, entertainment and recreation	7,009	10,858	4.53	0.9	1.0
Accommodation and food services	23,263	33,621	3.78	3.0	2.9
Other Private Services	42,522	73,532	5.63	5.5	6.4

- 1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;
- 2 Growth rates calculated as the arithmetic average of annual growth rates.

the case of mining and oil and gas extraction from 7.9 per cent in 2000 to 9.7 per cent in 2010, while in construction from 6.5 per cent to 9.4 per cent. At the same time, nominal GDP in the manufacturing sector fell 1.22 per cent per year, causing a marked decline in the sector's share of business sector nominal GDP, from 24.4 per cent in 2000 to 14.4 per cent in 2010.<sup>11</sup>

Table 2 presents two sets of price deflators, the first one calculated using a fixed-base Paasche price index and the second one calculated using a chained Fisher price index. It is clear from the numbers that, for the time period in question, the

differences between the two sets of deflators are minor. The only two sectors where there is a (potentially) significant difference between price deflators are manufacturing (which saw prices rising 0.70 per cent per year according to the constant price deflator and 0.44 per cent per year according to the chained price deflator) and wholesale trade (1.52 per cent per year versus 1.93 per cent per year).

Almost 60 per cent of the total increase in business sector nominal GDP was caused by rising prices. At the business sector level, prices rose at an average annual rate of 2.38 per cent according

11 Instead of using only starting and end points of a particular series, growth rates presented in this article were calculated as the period average of annual growth rates, e.g. for the 2000-2010 period, reported growth rates are the average of the annual growth experienced in 2001, 2002, ..., 2010. This ensures that growth rates are consistent with our estimates of sectoral contributions to aggregate labour productivity growth, which were calculated on a year-to-year basis. Although sectoral contribution estimates could have been calculated for the entire 2000-2010 period, since contributions are crucially dependent of output and labour shares in the *initial period*, large swings in these shares in subsequent periods could bias estimated contributions significantly.



**Table 2****Implicit Price Deflators for Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010**

	Prices, 2000 (2002 = 100) $P_{2000}^i$	Prices, 2010 (2002 = 100) $P_{2010}^i$	Ave. Annual Growth (%)	Relative Prices, 2000 (%) $P_{2000}^i$	Relative Prices, 2010 (%) $P_{2010}^i$
<b>A) Constant 2002 Dollars</b>					
Business sector industries	98.0	123.7	2.38	100.0	100.0
Agriculture, forestry, fishing and hunting	84.1	87.1	0.63	85.9	70.4
Mining and oil and gas extraction	116.7	201.8	7.79	119.1	163.2
Utilities	97.5	111.2	1.39	99.5	89.9
Construction	96.1	147.6	4.44	98.1	119.3
Manufacturing	98.3	105.3	0.70	100.4	85.1
Wholesale trade	99.4	115.4	1.52	101.4	93.3
Retail trade	99.1	114.0	1.42	101.2	92.2
Transportation and warehousing	94.1	122.6	2.69	96.0	99.1
Information and cultural industries	100.1	123.4	2.12	102.1	99.7
FIRE	97.6	116.8	1.81	99.6	94.5
Professional, scientific and technical services	95.3	128.3	3.03	97.2	103.8
ASWMRS	93.9	124.8	2.90	95.8	100.9
Arts, entertainment and recreation	91.8	122.5	2.95	93.7	99.0
Accommodation and food services	95.3	127.8	2.98	97.3	103.3
Other Private Services	93.2	128.9	3.30	95.1	104.2
<b>B) Chained 2002 Dollars</b>					
Business sector industries	98.0	123.2	2.33	100.0	100.0
Agriculture, forestry, fishing and hunting	86.6	90.6	0.70	88.4	73.5
Mining and oil and gas extraction	118.2	201.8	7.77	120.6	163.8
Utilities	95.2	110.5	1.58	97.1	89.7
Construction	95.9	145.8	4.33	97.8	118.3
Manufacturing	99.2	103.6	0.44	101.2	84.1
Wholesale trade	97.0	117.3	1.93	98.9	95.2
Retail trade	97.7	114.5	1.61	99.6	92.9
Transportation and warehousing	94.5	122.7	2.66	96.3	99.6
Information and cultural industries	99.7	123.5	2.18	101.7	100.3
FIRE	98.0	117.1	1.80	99.9	95.1
Professional, scientific and technical services	94.6	129.0	3.16	96.5	104.7
ASWMRS	93.6	124.7	2.92	95.5	101.2
Arts, entertainment and recreation	91.4	122.5	2.99	93.3	99.5
Accommodation and food services	95.5	127.4	2.93	97.4	103.4
Other Private Services	93.2	129.8	3.37	95.1	105.3

1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

to the constant price deflator and 2.33 per cent according to the chained price deflator. The sectors that saw the most significant price increases were mining and oil and gas extraction (7.77-7.79 per cent per year) and construction (4.33-4.44 per cent per year). Although prices in manufacturing increased at a much slower rate than overall busi-

ness sector prices, the fact that they did increase implies that real GDP growth in the sector was even lower than nominal GDP growth.

In fact, this is exactly what Table 3 shows, with real GDP in the manufacturing sector declining 1.85 per cent per year according to the constant price deflator or 1.64 per cent

**Table 3**

**Real GDP in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010**

	Real GDP, 2000 (\$ millions)	Real GDP, 2010 (\$ millions)	Ave. Annual Growth (%)	Real GDP Shares, 2000 (%)	Real GDP Shares, 2010 (%)
	$X_{2000}^i$	$X_{2010}^i$		$\frac{X_{2000}^i}{X_{2000}}$	$\frac{X_{2010}^i}{X_{2010}}$
<b>A) Constant 2002 Dollars</b>					
Business sector industries	785,491	922,567	1.65	100.0	100.0
Agriculture, forestry, fishing and hunting	26,312	28,711	1.11	3.3	3.1
Mining and oil and gas extraction	52,183	54,958	0.60	6.6	6.0
Utilities	26,914	30,403	1.28	3.4	3.3
Construction	51,655	72,576	3.56	6.6	7.9
Manufacturing	190,617	155,727	-1.85	24.3	16.9
Wholesale trade	51,256	69,891	3.22	6.5	7.6
Retail trade	51,766	75,893	3.92	6.6	8.2
Transportation and warehousing	46,670	54,719	1.65	5.9	5.9
Information and cultural industries	32,126	43,152	3.03	4.1	4.7
FIRE	110,890	154,182	3.36	14.1	16.7
Professional, scientific and technical services	45,731	59,929	2.76	5.8	6.5
ASWMRS	21,697	30,208	3.42	2.8	3.3
Arts, entertainment and recreation	7,634	8,864	1.53	1.0	1.0
Accommodation and food services	24,406	26,313	0.77	3.1	2.9
Other Private Services	45,633	57,042	2.26	5.8	6.2
<b>B) Chained 2002 Dollars</b>					
Business sector industries	785,057	926,103	1.70	100.0	100.0
Agriculture, forestry, fishing and hunting	25,549	27,593	0.95	3.3	3.0
Mining and oil and gas extraction	51,519	54,967	0.71	6.6	5.9
Utilities	27,560	30,602	1.12	3.5	3.3
Construction	51,757	73,467	3.67	6.6	7.9
Manufacturing	188,914	158,307	-1.64	24.1	17.1
Wholesale trade	52,511	68,802	2.80	6.7	7.4
Retail trade	52,536	75,564	3.72	6.7	8.2
Transportation and warehousing	46,472	54,647	1.67	5.9	5.9
Information and cultural industries	32,242	43,084	2.97	4.1	4.7
FIRE	110,515	153,801	3.37	14.1	16.6
Professional, scientific and technical services	46,068	59,612	2.63	5.9	6.4
ASWMRS	21,750	30,248	3.40	2.8	3.3
Arts, entertainment and recreation	7,665	8,861	1.49	1.0	1.0
Accommodation and food services	24,362	26,395	0.82	3.1	2.9
Other Private Services	45,622	56,654	2.19	5.8	6.1

1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

per year according to the chained price deflator. It is interesting to note, also, that most of the nominal GDP growth experienced by the mining and oil and gas extraction sector was due to price increases. Real GDP growth in

the sector was only 0.60-0.71 per cent per year during the 2000-2010 period. The construction sector, on the other hand, saw not only rapid price increases but also fast real GDP growth. The sector had the second highest

real growth rate among all two-digit NAICS sectors (3.56-3.67 per cent per year), only behind retail trade (3.72-3.92 per cent per year). Other sectors that experienced robust real GDP growth were FIRE (3.36-3.37 per cent per year) and administration and support, waste management and remediation services (ASWMRS) (3.40-3.42 per cent per year). At the business sector level, real GDP grew at an average annual rate of 1.65-1.70 per cent during the 2000-2010 period.

While nominal GDP in mining and oil and gas extraction as a share of business sector GDP increased substantially from 2000 to 2010, the sector's real GDP share actually fell during the period, from 6.6 per cent in 2000 to 5.9-6.0 per cent (depending on which deflator is used). Manufacturing also saw a marked decline in its real GDP share, from 24.1-24.3 per cent to 16.9-17.1 per cent, although the magnitude of this decline was not as marked as it was in nominal terms. The construction sector's real GDP share, on the other hand, increased in the period, from 6.6-6.7 per cent to 7.9 per cent. Another interesting development was the increase in the FIRE sector's real GDP share, from 14.1 per cent to 16.6-16.7 per cent.

Hours worked in the Canadian business sector increased at an average annual rate of 0.78 per cent during the 2000-2010 period (Table 4). Hours worked saw particularly fast growth in mining and oil and gas extraction (3.91 per cent per year), construction (3.66 per cent per year), and ASWMRS (3.37 per cent per year). Conversely, agriculture, forestry, fishing and hunting (-2.91 per cent per year) and manufacturing (-2.50 per cent per year) experienced a decline in total hours worked.

The changes in sectoral hours worked as a share of total hours worked in the business sector during the 2000s were not as drastic as those seen in terms of nominal GDP or real

GDP shares. The two most significant changes were in construction, where the hours worked share increased from 8.3 per cent in 2000 to 11.0 per cent in 2010, and manufacturing, where the share decreased from 18.3 per cent to 13.1 per cent.

Using our two sets of real GDP estimates and hours worked, labour productivity estimates were constructed for the business sector and two-digit NAICS sectors in Canada from 2000 to 2010 (Table 5). During the period, labour productivity in the Canadian business sector grew at an average annual rate of 0.86 per cent according to the constant 2002 dollar estimates – from \$35.57 per hour in 2000 to \$38.74 per hour in 2010 – and 0.91 per cent according to the chained 2002 dollar estimates – from \$35.55 per hour to \$38.89 per hour. This difference is so small, however, that it seems safe to assume it is not particularly relevant.

Since labour input is the same for both sets of labour productivity estimates, the sole source of differences between the two sets of estimates is real output. Thus, exactly as seen when price deflator and real output trends were discussed, there were only two sectors where a substantial difference in labour productivity growth rates could be observed: first, wholesale trade, where labour productivity grew 3.27 per cent per year according to the constant dollar estimates, but only 2.86 per cent per year according to the chained dollar estimates; and second, manufacturing, where labour productivity growth was 0.61 per cent per year according to the constant dollar estimate and 0.85 per cent per year according to the chained dollar estimate. For all the other sectors, the differences in labour productivity growth between the two sets of estimates were minor.

During the 2000-2010 period, the two-digit NAICS sector that experienced the fastest

**Table 4****Hours Worked in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010**

	Hours Worked, 2000 (millions) $L_{2000}^i$	Hours Worked, 2010 (millions) $L_{2010}^i$	Ave. Annual Growth (%)	Hours Worked Shares, 2000 (%) $L_{2000}^i$	Hours Worked Shares, 2010 (%) $L_{2010}^i$
Business sector industries	22,083	23,812	0.78	100.0	100.0
Agriculture, forestry, fishing and hunting	997	737	-2.91	4.5	3.1
Mining and oil and gas extraction	324	461	3.91	1.5	1.9
Utilities	167	202	2.02	0.8	0.8
Construction	1,833	2,610	3.66	8.3	11.0
Manufacturing	4,037	3,114	-2.50	18.3	13.1
Wholesale trade	1,597	1,584	-0.04	7.2	6.7
Retail trade	2,754	3,145	1.36	12.5	13.2
Transportation and warehousing	1,412	1,479	0.51	6.4	6.2
Information and cultural industries	631	691	0.95	2.9	2.9
FIRE	1,644	1,937	1.66	7.4	8.1
Professional, scientific and technical services	1,566	1,926	2.11	7.1	8.1
ASWMRS	1,014	1,406	3.37	4.6	5.9
Arts, entertainment and recreation	370	459	2.28	1.7	1.9
Accommodation and food services	1,660	1,713	0.34	7.5	7.2
Other Private Services	2,076	2,348	1.25	9.4	9.9

1 FIRE Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

labour productivity growth was agriculture, forestry, fishing and hunting (4.12-4.25 per cent per year), followed by wholesale trade (2.86-3.27 per cent) and retail trade (2.35-2.54 per cent). Conversely, the sectors that saw the worst labour productivity performances were mining and oil and gas extraction (-2.80/-2.63 per cent per year), arts, entertainment and recreation (-0.65/-0.61 per cent), and utilities (-0.66/-0.51 per cent).

In terms of labour productivity levels, the sectors with the highest levels in 2010 were utilities (\$150.51-151.50 per hour), mining and oil and gas extraction (\$119.21-119.23 per hour), and FIRE (\$79.40-79.60 per hour). The lowest labour productivity levels could be found in accommodation and food services (\$15.36-15.41 per hour), arts, entertainment and recreation (\$19.31 per hour), and ASWMRS (\$21.49-21.51 per hour).

### **Sectoral Contributions to Business Sector Labour Productivity Growth in Canada, 2000-2010**

Using the TRAD, CSLS, and GEAD decomposition formulas, contributions of two-digit NAICS sectors to business sector labour productivity growth in Canada during the 2000-2010 period were calculated. Two sets of estimates were constructed for each of the three formulas – one using real output in constant 2002 dollars (Table 6) and the other using real output in chained 2002 dollars (Table 7). A comparison between Tables 6 and 7 shows that, while the estimated sectoral contributions differ significantly from formula to formula, the differences due to the use of real GDP in constant prices or in chained prices are relatively small and do not alter the overall results of each decomposition formula. The main difference between the two

**Table 5**  
**Labour Productivity in Canada, Business Sector and Two-Digit NAICS Sectors, 2000-2010**

	Labour Productivity, 2000 (\$ per hour)	Labour Productivity, 2010 (\$ per hour)	Ave. Annual Growth (%)	Relative Labour Productivity, 2010 (%)	Relative Labour Productivity, 2010 (%)
	$Z_{2000}^i$	$Z_{2010}^i$		$\frac{Z_{2010}^i}{Z_{2000}^i}$	$\frac{Z_{2010}^i}{Z_{2010}}$
<b>A) Constant 2002 Dollars</b>					
Business sector industries	35.57	38.74	0.86	100.0	100.0
Agriculture, forestry, fishing and hunting	26.39	38.96	4.25	74.2	100.6
Mining and oil and gas extraction	161.06	119.21	-2.80	452.8	307.7
Utilities	161.16	150.51	-0.51	453.1	388.5
Construction	28.18	27.81	-0.10	79.2	71.8
Manufacturing	47.22	50.01	0.61	132.7	129.1
Wholesale trade	32.10	44.12	3.27	90.2	113.9
Retail trade	18.80	24.13	2.54	52.8	62.3
Transportation and warehousing	33.05	37.00	1.17	92.9	95.5
Information and cultural industries	50.91	62.45	2.13	143.1	161.2
FIRE	67.45	79.60	1.69	189.6	205.4
Professional, scientific and technical services	29.20	31.12	0.65	82.1	80.3
ASWMRS	21.40	21.49	0.06	60.2	55.5
Arts, entertainment and recreation	20.63	19.31	-0.61	58.0	49.8
Accommodation and food services	14.70	15.36	0.45	41.3	39.6
Other Private Services	21.98	24.29	1.02	61.8	62.7
<b>B) Chained 2002 Dollars</b>					
Business sector industries	35.55	38.89	0.91	100.0	100.0
Agriculture, forestry, fishing and hunting	25.63	37.44	4.12	72.1	96.3
Mining and oil and gas extraction	159.01	119.23	-2.63	447.3	306.6
Utilities	165.03	151.50	-0.66	464.2	389.5
Construction	28.24	28.15	0.00	79.4	72.4
Manufacturing	46.80	50.84	0.85	131.6	130.7
Wholesale trade	32.88	43.44	2.86	92.5	111.7
Retail trade	19.08	24.03	2.35	53.7	61.8
Transportation and warehousing	32.91	36.95	1.20	92.6	95.0
Information and cultural industries	51.10	62.35	2.07	143.7	160.3
FIRE	67.22	79.40	1.70	189.1	204.2
Professional, scientific and technical services	29.42	30.95	0.52	82.7	79.6
ASWMRS	21.45	21.51	0.05	60.3	55.3
Arts, entertainment and recreation	20.72	19.31	-0.65	58.3	49.6
Accommodation and food services	14.68	15.41	0.50	41.3	39.6
Other Private Services	21.98	24.13	0.95	61.8	62.0

1 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;

2 Growth rates calculated as the arithmetic average of annual growth rates.

sets of estimates is simply that sectoral contributions calculated using the TRAD and CSLS formulas do not sum up to business sector labour productivity growth when real GDP is in chained 2002 dollars. Given that these are minor differences, this section focuses on the first set of estimates, which uses real GDP in constant 2002 dollars.

At the aggregate economy level, the TRAD and CSLS formulas tell exactly the same story. According to both formulas, the entirety of business sector labour productivity growth in Canada during the 2000-2010 period (0.86 per cent per year) is explained by within-sector effects (WSE). In fact, the WSE contribution was higher than actual labour productivity growth –

**Table 6**

**Sectoral Contributions to Business Sector Labour Productivity Growth in Canada,  
Real GDP in Constant 2002 Dollars, 2000-2010**

	TRAD				CSLS				GEAD			
	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE
<b>A) Percentage Point Contributions</b>												
Business sector industries	0.86	0.95	-0.03	-0.06	0.86	0.95	-0.03	-0.06	0.86	0.82	0.23	-0.18
Agriculture, forestry, fishing and hunting	0.00	0.13	-0.11	-0.01	0.15	0.13	0.03	-0.01	-0.05	0.10	-0.14	-0.01
Mining and oil and gas extraction	-0.01	-0.18	0.20	-0.03	-0.06	-0.18	0.15	-0.03	0.26	-0.25	0.65	-0.14
Utilities	0.01	-0.02	0.04	-0.01	0.01	-0.02	0.04	-0.01	-0.02	-0.02	0.02	-0.01
Construction	0.19	-0.01	0.21	0.00	-0.08	-0.01	-0.06	0.00	0.36	-0.02	0.39	0.00
Manufacturing	-0.56	0.11	-0.67	0.00	-0.04	0.11	-0.15	0.00	-0.83	0.10	-0.93	-0.01
Wholesale trade	0.17	0.23	-0.06	0.00	0.22	0.23	0.00	0.00	0.11	0.23	-0.11	-0.01
Retail trade	0.23	0.18	0.04	0.00	0.15	0.18	-0.03	0.00	0.15	0.18	-0.02	0.00
Transportation and warehousing	0.05	0.07	-0.02	0.00	0.07	0.07	0.00	0.00	0.07	0.06	0.00	0.00
Information and cultural industries	0.10	0.09	0.01	0.00	0.09	0.09	0.00	0.00	0.09	0.09	0.00	0.00
FIRE	0.39	0.25	0.14	0.00	0.32	0.25	0.07	0.00	0.30	0.24	0.05	0.00
Professional, scientific and technical services	0.12	0.04	0.08	0.00	0.02	0.04	-0.02	0.00	0.16	0.03	0.13	0.00
ASWMRS	0.08	0.00	0.08	0.00	-0.05	0.00	-0.05	0.00	0.09	0.00	0.09	0.00
Arts, entertainment and recreation	0.01	-0.01	0.01	0.00	-0.02	-0.01	-0.01	0.00	0.01	-0.01	0.02	0.00
Accommodation and food services	0.00	0.01	-0.01	0.00	0.03	0.01	0.02	0.00	0.02	0.01	0.00	0.00
Other Private Services	0.09	0.06	0.03	0.00	0.04	0.06	-0.02	0.00	0.14	0.06	0.08	0.00
<b>B) Per Cent Contributions</b>												
Business sector industries	100.0	110.1	-3.6	-6.6	100.0	110.1	-3.6	-6.6	100.0	94.9	26.5	-21.4
Agriculture, forestry, fishing and hunting	0.3	14.5	-13.1	-1.1	16.9	14.5	3.4	-1.0	-5.5	11.7	-15.7	-1.5
Mining and oil and gas extraction	-1.6	-21.1	22.8	-3.3	-7.1	-21.1	17.3	-3.4	30.1	-29.4	75.2	-15.7
Utilities	1.7	-2.4	5.2	-1.0	0.7	-2.4	4.1	-1.0	-2.0	-2.2	1.8	-1.5
Construction	22.3	-1.7	24.1	-0.1	-8.8	-1.7	-6.7	-0.4	41.8	-2.5	44.8	-0.5
Manufacturing	-64.7	13.0	-77.8	0.1	-4.1	13.0	-17.6	0.4	-96.3	12.2	-107.6	-0.9
Wholesale trade	19.3	26.7	-6.9	-0.4	26.1	26.7	-0.2	-0.4	12.2	26.1	-13.2	-0.6
Retail trade	26.4	21.4	4.9	0.0	17.8	21.4	-3.6	0.0	17.8	20.9	-2.9	-0.3
Transportation and warehousing	5.8	7.8	-1.9	-0.2	7.9	7.8	0.2	-0.2	7.8	7.5	0.4	-0.1
Information and cultural industries	11.3	10.6	1.1	-0.3	10.9	10.6	0.6	-0.3	10.1	10.6	-0.1	-0.4
FIRE	45.3	29.3	15.9	0.1	37.2	29.3	7.9	0.0	34.7	28.3	6.1	0.3
Professional, scientific and technical services	13.9	4.2	9.7	0.0	2.3	4.2	-1.8	0.0	18.5	4.0	14.5	0.0
ASWMRS	9.1	0.2	9.0	-0.1	-6.3	0.2	-6.2	-0.2	10.8	0.1	10.7	-0.1
Arts, entertainment and recreation	0.8	-0.7	1.7	-0.1	-2.0	-0.7	-1.2	-0.1	1.4	-0.7	2.3	-0.2
Accommodation and food services	0.0	1.5	-1.5	0.0	3.8	1.5	2.3	0.0	2.1	1.5	0.5	0.0
Other Private Services	10.2	6.9	3.3	0.0	5.0	6.9	-2.0	0.1	16.6	6.7	9.7	0.2

- 1 TC - Total Contribution; WSE - Within-Sector Effect; RLE - Reallocation Level Effect; RGE - Reallocation Growth Effect.
- 2 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;
- 3 Growth rates calculated as the arithmetic average of annual growth rates.

0.95 percentage points or 110.1 per cent of business sector labour productivity growth. Aggregate labour productivity growth was dampened

by negative reallocation level (RLE) and reallocation growth (RGE) effects, with the RLE reducing growth by 0.03 percentage points (-3.6

**Table 7**

**Sectoral Contributions to Business Sector Labour Productivity Growth in Canada,  
Real GDP in Chained 2002 Dollars, 2000-2010**

	TRAD				CSLS				GEAD			
	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE	TC	WSE	RLE	RGE
<b>A) Percentage Point Contributions</b>												
Business sector industries	0.87	0.96	-0.03	-0.06	0.87	0.96	-0.03	-0.06	0.91	0.84	0.27	-0.20
Agriculture, forestry, fishing and hunting	0.00	0.12	-0.11	-0.01	0.14	0.12	0.03	-0.01	-0.05	0.10	-0.13	-0.01
Mining and oil and gas extraction	-0.01	-0.17	0.20	-0.03	-0.05	-0.17	0.15	-0.03	0.27	-0.23	0.65	-0.15
Utilities	0.01	-0.03	0.04	-0.01	0.00	-0.03	0.04	-0.01	-0.02	-0.02	0.02	-0.01
Construction	0.20	-0.01	0.21	0.00	-0.07	-0.01	-0.06	0.00	0.36	-0.01	0.38	0.00
Manufacturing	-0.51	0.17	-0.67	0.00	0.02	0.17	-0.15	0.00	-0.82	0.15	-0.97	-0.01
Wholesale trade	0.14	0.20	-0.06	0.00	0.20	0.20	0.00	0.00	0.11	0.20	-0.08	-0.01
Retail trade	0.21	0.17	0.04	0.00	0.14	0.17	-0.03	0.00	0.16	0.17	-0.01	0.00
Transportation and warehousing	0.05	0.07	-0.02	0.00	0.07	0.07	0.00	0.00	0.07	0.07	0.00	0.00
Information and cultural industries	0.10	0.09	0.01	0.00	0.09	0.09	0.00	0.00	0.09	0.09	0.00	0.00
FIRE	0.39	0.25	0.14	0.00	0.32	0.25	0.07	0.00	0.30	0.25	0.06	0.00
Professional, scientific and technical services	0.11	0.03	0.08	0.00	0.01	0.03	-0.02	0.00	0.16	0.03	0.14	0.00
ASWMRS	0.08	0.00	0.08	0.00	-0.05	0.00	-0.05	0.00	0.09	0.00	0.09	0.00
Arts, entertainment and recreation	0.01	-0.01	0.01	0.00	-0.02	-0.01	-0.01	0.00	0.01	-0.01	0.02	0.00
Accommodation and food services	0.00	0.01	-0.01	0.00	0.03	0.01	0.02	0.00	0.02	0.01	0.00	0.00
Other Private Services	0.08	0.06	0.03	0.00	0.04	0.06	-0.02	0.00	0.15	0.05	0.09	0.00
<b>B) Per Cent Contributions</b>												
Business sector industries	100.0	110.5	-3.2	-7.3	100.0	110.5	-3.2	-7.3	100.0	92.3	30.0	-22.3
Agriculture, forestry, fishing and hunting	-0.1	13.8	-12.7	-1.1	16.5	13.8	3.7	-1.0	-5.1	10.9	-14.8	-1.3
Mining and oil and gas extraction	-0.6	-19.7	22.7	-3.6	-6.2	-19.7	17.3	-3.7	29.4	-25.6	72.0	-17.1
Utilities	1.0	-3.1	5.1	-1.0	-0.1	-3.1	4.1	-1.0	-1.7	-2.7	2.6	-1.6
Construction	23.2	-0.9	24.2	-0.1	-7.8	-0.9	-6.5	-0.4	40.1	-1.5	42.1	-0.5
Manufacturing	-58.5	19.3	-77.5	-0.4	1.9	19.3	-17.5	0.0	-90.8	16.8	-106.7	-0.9
Wholesale trade	15.9	23.2	-6.8	-0.5	22.7	23.2	-0.1	-0.4	11.9	21.8	-9.3	-0.6
Retail trade	24.6	19.7	4.9	0.0	16.1	19.7	-3.6	0.0	17.3	18.4	-1.0	-0.2
Transportation and warehousing	5.9	8.0	-1.9	-0.2	8.1	8.0	0.3	-0.2	7.7	7.3	0.4	-0.1
Information and cultural industries	11.0	10.3	1.0	-0.3	10.5	10.3	0.5	-0.3	9.8	9.9	0.3	-0.3
FIRE	45.0	29.2	15.7	0.1	37.0	29.2	7.8	0.0	33.6	27.1	6.3	0.2
Professional, scientific and technical services	12.9	3.3	9.6	0.0	1.4	3.3	-1.9	-0.1	17.9	3.0	14.9	0.0
ASWMRS	9.0	0.1	8.9	-0.1	-6.3	0.1	-6.2	-0.2	10.4	0.1	10.4	-0.1
Arts, entertainment and recreation	0.8	-0.8	1.7	-0.1	-2.1	-0.8	-1.2	-0.1	1.4	-0.7	2.3	-0.2
Accommodation and food services	0.2	1.7	-1.5	0.0	3.9	1.7	2.3	0.0	2.1	1.6	0.5	0.0
Other Private Services	9.7	6.4	3.3	0.0	4.4	6.4	-2.0	0.1	16.0	6.0	9.9	0.2

- 1 TC - Total Contribution; WSE - Within-Sector Effect; RLE - Reallocation Level Effect; RGE - Reallocation Growth Effect.
- 2 FIRE - Finance, insurance, real estate, rental and leasing; ASWMRS - Administration and support, waste management and remediation services;
- 3 Growth rates calculated as the arithmetic average of annual growth rates.

per cent) and the RGE accounting for a 0.06 percentage point (-6.6 per cent) reduction in growth.

The differences between the two formulas emerge when the role of each two-digit NAICS sector in explaining business sector labour pro-

ductivity growth is analysed separately. In the TRAD formula, the FIRE sector was responsible for almost half of aggregate labour productivity growth – 0.39 percentage points or 45.3 per cent of overall growth. Retail trade (0.23 percentage points or 26.4 per cent of total growth), construction (0.19 percentage points or 22.3 per cent), and wholesale trade (0.17 percentage points or 19.3 per cent) were also fundamental in driving aggregate labour productivity growth in the period. The economy's labour productivity performance was hindered, however, by the massive negative contribution of the manufacturing sector (-0.56 percentage points or -64.7 per cent of total growth), which was caused by a very strong (and negative) RLE. Other than manufacturing, the only sector which had a negative (albeit very small) contribution to business sector labour productivity growth was mining and oil and gas extraction.

In the CSLS formula, FIRE is still the sector with the highest contribution to business sector labour productivity growth (0.32 percentage points or 37.2 per cent of total growth), although its contribution is smaller than it was in the TRAD formula. Other sectors that played an important role in driving aggregate labour productivity growth according to the CSLS formula were wholesale trade (0.22 percentage points or 26.1 per cent of total growth), retail trade (0.15 percentage points or 17.8 per cent), and agriculture, forestry, fishing and hunting (0.15 percentage points or 16.9 per cent). Note that, while construction had an important positive contribution in the TRAD formula, it had a *negative* contribution in the CSLS formula (-0.08 percentage points or -8.8 per cent of total growth). Furthermore, the contribution of manufacturing in the CSLS formula, while still negative, was not nearly as strong as it was in the TRAD formula (-0.04 percentage points or -4.1 per cent of total growth). It is interesting to note, also, that five out of the 15 two-digit

NAICS sectors had a negative contribution to aggregate labour productivity growth according to the CSLS formula (versus two in the TRAD formula).

Recalling our discussion about each decomposition formula in the previous section, it is clear that these differences are caused solely by how the RLE and RGE are calculated in the TRAD and CSLS formulas. Take the case of the construction sector, for instance, which had a positive RLE in the TRAD formula and a negative one in the CSLS formula. Since there was an increase in the sector's labour share (from 8.3 per cent in 2000 to 11.0 per cent in 2010) during the period, the TRAD formula sees the sector's RLE as positive. The CSLS formula, on the other hand, attributes to the sector a negative RLE because of its below-average labour productivity level.

What explains, however, the huge differences in the manufacturing sector's RLE? In the TRAD formula, the sector's RLE contributed -0.67 percentage points to aggregate labour productivity growth, while in the CSLS formula it contributed only -0.15 percentage points. This difference is explained by the fact that the TRAD formula depends on the ratio between the labour productivity level in manufacturing and in the business sector, whereas in the CSLS formula it depends on the difference between the two. Overall, as shown by Table 6, the TRAD formula produces RLE estimates with much higher magnitudes than the CSLS formula.

The GEAD formula provides a very different perspective on sectoral contributions to business sector labour productivity growth. First, at the aggregate economy level, the magnitude of the WSE in the GEAD formula is noticeably smaller than that of the TRAD and CSLS formulas (0.82 percentage points versus 0.95 percentage points). This difference is driven by the fact that, in the GEAD formula, the within-



sector effect is determined by nominal shares instead of real shares.

While the WSE still accounts for almost the entirety of business sector labour productivity growth in the period (94.9 per cent), the joint reallocation effects (RLE + RGE) now have a small positive contribution (5.1 per cent). More precisely, the RLE now has a positive sign, while the RGE retains its negative sign. What is more, the magnitude of both reallocation effects under the GEAD formula is significantly higher than in the other two formulas. In the GEAD formula, the RLE explained 0.23 percentage points of total labour productivity growth versus -0.03 percentage points in the TRAD and CSLS formulas. The same applies for the RGE, which explained -0.18 percentage points of aggregate productivity growth in the GEAD formula versus -0.06 percentage points in the TRAD and CSLS formulas.

According to the GEAD formula, the three sectors that contributed the most to business sector labour productivity growth were: construction (0.36 percentage points or 41.8 per cent of total growth), FIRE (0.30 percentage points or 34.7 per cent), and mining and oil and gas extraction (0.26 percentage points or 30.1 per cent).<sup>12</sup> In general, all sectors had positive contributions, with the exception of utilities; agriculture, forestry, fishing and hunting; and manufacturing. Of these three sectors, manufacturing was the only one where the magnitude of the contribution actually mattered, reducing aggregate labour productivity growth by -0.83 percentage points (or 96.3 per cent of total growth). Much like the TRAD formula, this was caused by a massive RLE – in fact, the RLE in

the GEAD formula was even larger than that of the TRAD formula.

### Three Decomposition Formulas, Three Stories

The comparison between the estimates produced by the TRAD, CSLS, and GEAD formulas highlights an important problem: despite some similarities, all three decomposition formulas paint very different pictures of which sectors drove labour productivity growth in the Canadian business sector during the 2000-2010 period. Why are estimated contributions so different? Which set of estimates provides a more accurate picture of economic reality?

The differences between the TRAD and CSLS formulas are caused solely by the way each formula assigns sectoral contributions due to reallocation effects. In the TRAD formula, for instance, a sector's RLE will be positive as long as its labour share increases, regardless of whether the sector had above-average or below-average labour productivity level. In the CSLS formula, however, a sector with below-average labour productivity level will have a negative RLE if its labour share increases.

In our opinion, the way the TRAD formula deals with reallocation effects is quite problematic. At the aggregate level, if labour moved to sectors with below-average labour productivity level (growth), the sign of the overall RLE (RGE) would be negative. Sectors with below-average labour productivity levels that experienced an increase in their labour share would, however, have a *positive* RLE (which would be offset by the negative RLE of the sectors with above-average labour productivity that experi-

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12 It is interesting to note that, for the 2000-2008 period, the contribution of mining and oil and gas extraction to business sector labour productivity growth was much higher. According to our GEAD formula estimates, the sector accounted for 0.77 percentage points of the average annual labour productivity growth of 0.90 per cent experienced by the Canadian economy in the period, slightly over 80 per cent of total growth. This impressive contribution of the mining and oil and gas sector to aggregate labour productivity growth was caused by the spike in oil prices in 2008. Our estimates are consistent with those seen in Almon and Tang (2011) (see Appendix Table in De Avillez (2012)).

enced a reduction in their labour share). The CSLS formula prevents this from happening by making reallocation effects a function of the difference between a sector's labour productivity level (growth) and the aggregate labour productivity level (growth).

Despite this advantage, some of the results of the CSLS formula can also be considered counterintuitive. When labour moves from a sector with below-average labour productivity level towards a sector with above-average labour productivity level, for instance, *both* sectors will have a positive RLE. The positive RLE of the low productivity sector, which seems unwarranted, happens exactly because people are leaving the sector. Although this dynamic represents a limitation of the CSLS formula, we still believe that the CSLS formula produces better reallocation effect estimates than the TRAD formula. Because of how they are specified, the CSLS reallocation effects tend to be well distributed among sectors, which minimizes the impact of strange reallocation dynamics, while the TRAD's reallocation effects tend to be concentrated in specific sectors, magnifying the dynamic discussed in the previous paragraph. In the end, however, an argument can be made for the impossibility of assigning reallocation effects across sectors in a definitive way.

The TRAD and CSLS formulas – which represent the “traditional” formulas analysed in this article – differ from the GEAD formula because they do not incorporate *price effects* into sectoral contributions. Sectoral contributions to aggregate labour productivity growth are calculated based solely on sectoral labour productivity and labour shares. In this sense, the TRAD and CSLS formulas capture only *quantity effects*. Sectoral contributions in both formulas represent how the increase in the volume of goods and services produced per hour in a particular sector (along with labour movements) affects the increase in the *volume* of goods and services pro-

duced per hour at the aggregate level. These formulas can therefore be seen as measuring the impact of (sectoral) *real* variables on aggregate labour productivity growth.

In the case of the GEAD formula, estimated contributions have a different meaning. A sector's contribution to aggregate productivity growth, while obviously dependent on the sector's labour productivity growth (and labour movements), is also dependent on how the economy values that sector's output, which is determined by relative prices. By incorporating price effects into contributions, the GEAD formula captures the overall *economic significance* of different sectors to aggregate labour productivity growth.

The case of the Canadian mining and oil and gas extraction sector clearly illustrates the difference between the GEAD and the other two decomposition formulas analysed in this article. In the CSLS and TRAD formulas, mining and oil and gas extraction had a *small, negative* contribution to business sector labour productivity growth during the 2000–2010 period. According to the GEAD formula, however, the sector had a *large, positive* contribution.

Looking only at real variables, mining and oil and gas did indeed contribute very little to overall business sector labour productivity growth in Canada during the 2000–2010 period. Real GDP in the sector increased only 0.60 per cent per year (versus 1.65 per cent per year at the business sector level); the sector's labour share did increase, from 1.5 per cent in 2000 to 1.9 per cent in 2010, but remained quite small; and labour productivity in the sector experienced a sharp drop of 2.80 per cent per year (versus an increase of 0.86 per cent per year at the business sector level). These developments are captured by the TRAD and CSLS formulas and result in a small, negative contribution of mining and oil and gas to business sector labour productivity growth.

When relative prices are included in the equation, the story looks very different. Mining and oil and gas prices roughly doubled during the period, increasing 7.79 per cent per year, while business sector prices rose only 2.38 per cent per year. The GEAD formula captures this shift in relative prices, which was more than enough to offset the lacklustre productivity performance of the mining and oil and gas extraction sector, causing it to have a large, positive contribution to business sector labour productivity growth. Thus, the GEAD formula captures the fact that mining and oil and gas extraction played a fundamental role in driving economic growth in Canada during this past decade.

The above discussion underlines that sectoral contributions calculated by the TRAD and CSLS formulas are not strictly comparable with those calculated by the GEAD formula. In the first two formulas, sectoral contributions are a function only of real variables, whereas in the GEAD formula they are also a function of changes in relative prices. From this perspective, it is impossible to say which set of estimates provides a more accurate picture of economic reality because the GEAD formula is, ultimately, measuring something very different from the TRAD and CSLS formulas.

## Conclusion

This article analysed sectoral contributions to business sector labour productivity growth in Canada during the 2000–2010 period using three different decomposition formulas – TRAD, CSLS, and GEAD. The first two formulas assume real output in constant prices, while the GEAD formula does not make any particular assumption regarding how real output estimates were constructed. All three formulas break down sectoral contributions into within-sector, reallocation level, and reallocation growth effects. The TRAD and CSLS formulas produce

the exact same estimates of within-sector effects, but allocate sectoral contributions due to the reallocation effects in different ways. The GEAD formula differs from the first two formulas in that it takes into account how movements in relative prices impact the three effects.

During the 2000–2010 period, business sector labour productivity increased at an average annual rate of 0.86 per cent (or 0.95 per cent, depending on how real GDP is calculated). At the aggregate economy level, the TRAD and CSLS formulas tell the same story, with the within-sector effect accounting for over 100 per cent of labour productivity growth in the period and the negative reallocation effects actually hindering growth. In terms of sectoral contributions, there were also important similarities between the estimates produced by the two formulas. In both formulas, FIRE was the sector that had the highest positive contribution to business sector labour productivity growth. Other sectors that played an important role in both formulas were wholesale and retail trade.

There were also, however, important differences in how the TRAD and CSLS formulas allocated sectoral contributions to business sector labour productivity growth. In the TRAD formula, construction had a strong, positive contribution to aggregate productivity growth, whereas in the CSLS formula the sector actually dampened productivity growth. Conversely, the CSLS formula attributes a somewhat important role to agriculture, forestry, fishing and hunting, whereas in the TRAD formula the sector's contribution is zero. The biggest difference between the two formulas can be seen in the role of manufacturing. In the TRAD formula, the reduction of the manufacturing sector's labour share caused a massive, negative reallocation level effect, which was more than enough to offset the sector's positive within-sector effect. In the CSLS formula, the sector also experienced a

negative reallocation effect, but its magnitude was much lower – less than one fourth of the magnitude of the TRAD's RLE – with the total contribution of the manufacturing sector to aggregate labour productivity growth being only slightly negative.

The story told by the GEAD formula, in turn, is quite different from that of the other two formulas. At the aggregate economy level, the within-sector effect is still the main driving force of business sector labour productivity growth, but the magnitude of the effect is lower than it was in the TRAD and CSLS formulas. Furthermore, the joint reallocation effects are actually positive. Construction, FIRE, and mining and oil and gas had the highest contributions to aggregate labour productivity growth, while manufacturing was the “villain” of the story, with a huge negative contribution to productivity growth.

The three decomposition formulas provide alternative narratives as to which sectors drove aggregate productivity growth in Canada over the past decade. Some parts of these three narratives point in the same direction. In particular, at the aggregate economy level, all three formulas show that most (if not all) of labour productivity growth was caused by within-sector productivity improvements, with sectoral reallocation either hindering productivity growth or improving it by a very small margin. When it comes to assessing the role of each individual sector in aggregate labour productivity growth the room for agreement is much smaller. It is true that there is some agreement regarding the importance of FIRE. Nevertheless, the differences appear to be much more significant. What is the actual role of construction, manufacturing, or mining and oil and gas extraction in explaining business sector labour productivity growth? Which formula produces more accurate estimates?

Although estimates produced by the CSLS and TRAD formulas can be compared – and, in

our opinion, the CSLS formula assigns reallocation effects in a more logical way than the TRAD formula – they are not strictly comparable to estimates calculated using the GEAD formula. In the TRAD and CSLS formulas, sectoral contributions reflect only the impact of *real* variables on aggregate labour productivity growth, whereas in the GEAD formula they also incorporate the effect of changes in *relative prices* to capture the overall economic significance of different sectors in the economy. This explains why, in the GEAD formula, mining and oil and gas had such a strong contribution to business sector labour productivity growth, despite the sector's lacklustre productivity performance.

From this perspective, it is impossible to say which set of estimates provides a more accurate picture of economic reality because the GEAD formula is, ultimately, measuring something very different from the TRAD and CSLS formulas. Instead of seeing estimates constructed by the GEAD and traditional formulas as “competing” narratives, it is more useful to see them as providing complementing stories about the role of different sectors in driving aggregate labour productivity growth.

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