the review of income and wealth

Review of Income and Wealth
Series 61, Number 4, December 2015
DOI: 10.1111/roiw.12139

ECONOMIC GROWTH IN CANADA AND THE UNITED STATES: SUPPLY-PUSH OR DEMAND-PULL?

BY JIANMIN TANG*

Industry Canada

AND

WEIMIN WANG

Statistics Canada

Understanding the nature of structural change and the sources of economic growth of an economy, especially the relative importance of different industries, is essential for policy-making. This paper estimates industry contribution to economic growth in both Canada and the United States. It argues that industry contribution should be evaluated on the basis of the performance of an industry in terms of creating economic value relative to other industries. In particular, it calls for the quantity and the price effects, which is consistent with real GDP in the chained-Fisher index that values the industry more when its price rises and less when its price declines. This is an important departure from the traditional methodologies that consider only quantity effect. This paper shows that the contribution from demand-driven industries is significantly more than the finding based on traditional thinking.

JEL Code: O47

Keywords: aggregate labor productivity, demand, economic growth, industry contribution, supply

1. INTRODUCTION

Understanding the performance of an economy is important for policy makers. The health of the economy is often indicated by real GDP growth, which is mainly driven by aggregate labor productivity growth over a longer period. These two aggregate measures are regularly published by national statistical agencies, and have been widely used to assess a country's overall economic performance and to develop the country's monetary and fiscal policies.

In this paper, we provide a new framework for estimating industry contribution to real GDP and aggregate labor productivity growth. The framework is developed on the basis of several observations. First, the economic value of industry output changes frequently, often at very different paces across industries. As a result, Statistics Canada, together with many other national statistical agencies, has been constructing real GDP following the chained-Fisher index, which

Note: We wish to thank Annette Ryan, Larry Shute, and Someshwar Rao for support, and two anonymous referees for helpful comments and suggestions. The views and opinions expressed here are our own and do not necessarily reflect those of Industry Canada or Statistics Canada.

*Correspondence to: Jianmin Tang, Industry Canada, 235 Queen Street, Room 1006C, Ottawa, Ontario, Canada K2G 7B8 (jianmin.tang@ic.gc.ca).

aggregates real output over industries using updated output prices as weights.[1] Thus, an industry will become more important for real GDP growth when the output price of this industry increases and vice versa.[2] This directly challenges some traditional methodologies used for estimating industry contribution to economic growth. For example, following a bottom-up approach as in Jorgenson *et al.* (2003) and Ho *et al.* (2004), aggregate real GDP is calculated as a translog index over industry real value added. Under that formulation, any industry can only contribute positively to economic growth through positive growth in real value added. This suggests the mining sector would have a minimal contribution to economic growth in Canada over the past decade, given that real value added growth in the sector was small over this period, despite substantial increase in commodity prices. The issue will be discussed in detail at the end of Section 3.2.

Second, changes in real output and its economic value of an industry are mainly driven by changes in supply and/or demand conditions. In the global economy, external forces play an important role in those changes, for instance, in the manufacturing and mining sectors.[3] Demand for certain manufactured-in-Canada goods has been reduced by supplies from low-cost producing countries, leading to a shrinking manufacturing sector in Canada.[4] At the same time, the rise of emerging economies has increased the demand for commodities, resulting in a booming mining sector in Canada.[5]

Finally, production resources in an economy do not necessarily move from low- to high-productive industries. Industry production is often guided by profit-seeking. In a "free" and efficient economy, production resources should and will be directed toward industries that can create most economic value and become most profitable, and should and will move away from less profitable ones. In fact, over

[1]The real GDP in the chained-Fisher index is calculated as the geometric mean of the Laspeyres and Paasche indices. The Laspeyres quantity index and the Paasche quantity index use, respectively, the previous and current year prices as weights for aggregation, with the weights being updated annually. Before the Fisher-chained index, real GDP was constructed using the fixed-weighted quantity index. Whelan (2002) suggests that the switch was particularly important in the 1990s because the combination of rapidly declining computer prices and large increases in nominal spending on computers would have caused substantial acceleration in fixed-weight measures of GDP growth. In addition, he believes that output per hour worked based on the chained index will be a better measure of the state of technology than the one based on the fixed-weight index. This is because the values assigned to goods and services at each period in time are likely to be better summarized by the structure of the relative prices prevailing at that time than by the relative price structure from some arbitrary base period.

[2]From the consumption side, real GDP growth reflects not only the growth of the quantity consumed of each product (good or service) but also the change in its value, whereas the value reflects the marginal utility of consuming an additional unit of a product and is measured by the product's market price (Nakamura, 2004). Similarly, on the production side, real GDP growth also reflects not only the growth of the produced quantity of each product, but also the change in the value of the additional unit produced to the producer, again measured by the market price.

[3]A change in market structure will also lead to a change in supply condition. In this paper, however, we focus on after-the-fact analysis and will not discuss further how supply/demand conditions change.

[4]Multinationals play an important role in the Canadian economy (Wang, 2014). They tend to be mobile, allocating production activities on a global basis to maximize profit. This may also be a factor influencing the demand condition in Canada.

[5]Note that the success of a Canadian industry depends on its competitiveness, which is influenced not only by productivity but also by input costs (labor, capital, and materials). Supply-driven industries may not necessarily contribute to economic growth, unless they can compete and improve demand for their products.

the past two decades, production resources in Canada have been mainly absorbed by service-producing industries despite their lower productivity on average than goods-producing industries (Figure C.1 in the Appendix).[6] The movement of production resources is particularly important for industry contribution to aggregate labor productivity performance, which will be discussed in Section 2.2.

With these observations, this paper extends the early studies by Tang and Wang (2004) and Almon and Tang (2011).[7] These studies argue that industry contribution to economic growth should be evaluated on the basis of an industry's performance in terms of economic value creation relative to other industries, which calls for the quantity and the price effects. By considering the price effect, the contributions of industries with increases in output prices relative to other industries, which are typically driven by improvements in demand conditions, are significantly larger than the findings based on traditional methodologies. The opposite is true for industries with declines in prices, typically driven by improvements in supply condition. For instance, according to de Avillez (2012), when the methodology by Tang and Wang (2004) was used, the mining sector contributed 0.27 percentage points to aggregate labor productivity growth in the Canadian business sector over the 2000–10 period. In contrast, it had a negative contribution of –0.01 percentage points when a traditional methodology was used. However, the drag of the manufacturing sector was –0.82 percentage points based on the new methodology, much larger than –0.51 percentage points when the traditional methodology was used.

The studies of Tang and Wang (2004) and Almon and Tang (2011) are based on value added for industry output. In this paper, we extend their framework from value added to gross output. The advantage of using gross output is that we can also study the impact of the use of intermediate inputs or outsourcing/offshoring, on economic growth.[8]

In addition, we examine supply-push and demand-pull and the implications for industry contributions to economic growth. In practice, we cannot separate demand shift from supply shift, but we do observe the net shift. In this paper, we refer to net demand shift as demand-pull and net supply shift as supply-push. By demand-pull, we mean that a change in the output (in terms of real output and relative output price) of an industry in a country is mainly driven by the movement of the demand curve (e.g., crude oil production after 2002) for the industry in that country (Figure C.2 in the Appendix). Similarly, by supply-push we mean that a change in the output is mainly driven by the shift in the supply curve (e.g., electronics due to technology progress or clothing due to cheap labor in emerging economies). An industry is associated with either supply-push or demand-pull, identified by the signs of changes in real gross output and its price in the industry.

[6]This is consistent with the cost-disease model (Baumol, 1967).

[7]Diewert (2008) confirms the methodology by Tang and Wang (2004) by providing an alternative formulation. Compared to traditional methodologies, Dumagan (2013) shows that Tang and Wang (2004) produced superior estimates from both an empirical and an analytical point of view.

[8]Offshoring is linked to economic growth. For a discussion of offshoring in Canada, see Tang (2010) or Tang and do Livramento (2010).

The actual change in output and its price in the industry depend, in complex ways, on the balancing supply and demand conditions. A change in either supply or demand conditions will affect output and its price. For example, without any change in the industry's production technology, an improved demand for an industry's product leads to an increase in both output and its price. On the other hand, given the demand, technology advancement, or productivity gain in an industry increases output and reduces output price.

Furthermore, we compare Canada and the United States in industry contribution to economic growth and highlight important differences. While Canada and the United States have many similarities, they also differ in many aspects. One of the major differences between the two economies is in industry structure. With its abundance in resources, the Canadian economy relies more on resource-based industries (i.e., mining, wood, and other resource-based manufacturing) while in the United States, the world technology leader and innovator, the economy is concentrated relatively more in high-tech industries and some service industries (i.e., computer and electronics, finance and insurance, and business services) (Almon and Tang, 2011). These differences may have important implications for the sources of economic growth, as those industries experience different demand and supply shocks. It is expected that with the difference in industry structure, Canada and the United States will follow different trajectories in economic growth. The Canadian economy has performed well during and after the recent financial crisis. In part, it has been buoyed by strong commodity prices. A high demand for commodities has resulted in a strong performance by the resource sector, which has masked the troubled manufacturing sector.

Thus, on the basis of gross output, this paper develops an analytical framework to study industry contribution to economic growth, considering the impact of the use of intermediate inputs. As a fundamental departure from traditional methods that concern only the quantity effect and ignore the price effect,[9] this paper measures industry contribution according to the significance of each industry in creating economic value, taking into account not only how much an industry has produced (the quantify effect) but also the economic value of the output (the price effect). The price effect, together with the quantity effect, allows policymakers to evaluate, improve, or develop industry policies to facilitate an efficient allocation of productive resources among industries to accelerate economic growth.

[9]Many traditional decomposition techniques for industry contribution to real GDP growth are based on real GDP in the fixed-weighted Laspeyres index (e.g., Wolff, 2000; van Ark *et al.*, 2002). For such an aggregation, industry outputs over a period are evaluated at their base-year prices, leading to no price effect. Because of this, those techniques will necessarily overestimate the importance of industries with price decreases and underestimate the importance of industries with price increases. The problem has become substantial with the revolutionary advances in information and communication technologies whose prices have declined dramatically year over year and with recent strong demand from emerging economies for commodities whose prices have skyrocketed since 2000. Interestingly, by construction, those techniques will show the mining sector having a minimal contribution to economic growth in Canada in post-2000 since real output in the sector has not increased much despite a large improvement in commodity prices since 2000. But, in reality, the resource sector has been the driving force of economic growth in Canada over this period.

2. A Framework for Measuring Industry Contribution to Economic Growth

This section develops a framework to measure industry contribution to growth in real GDP and aggregate labor productivity, and associates industry contribution with the changes in industry-specific supply and demand conditions.

2.1. *Industry Contribution to Real GDP Growth*

To establish a linkage in real output between the aggregate and industries, this paper follows a top-down approach in which aggregate real GDP is decomposed into industry components. Output at the industry level is gross output. Unlike value added, gross output also allows one to discuss the impact of outsourcing or offshoring on economic growth. The gross output concept is widely used for studying economic growth.[10]

Define V, V^r and P^v as nominal GDP, real GDP, and GDP implicit deflator, respectively.[11] In addition, let v_i be the nominal value added of industry i. The sum of industry nominal value added is equal to nominal GDP, that is, $V = \sum_i v_i$. For a given year, real GDP can be decomposed into its industry components:

$$
\begin{aligned}
V^r &= \frac{\sum_i v_i}{P^v} \\
&= \frac{\sum_i (y_i - m_i)}{P^v} \\
&= \sum_i \left(\frac{p_i^y y_i^r - p_i^m m_i^r}{P^v} \right) \\
&= \sum_i \left(\tilde{p}_i^y y_i^r - \tilde{p}_i^m m_i^r \right),
\end{aligned} \tag{1}
$$

where:

y_i, y_i^r and p_i^y are the nominal gross output, the real gross output, and the gross output deflator of industry i;

m_i, m_i^r and p_i^m are the nominal intermediate inputs, the real intermediate inputs, and the intermediate input deflator of industry i; and

$\tilde{p}_i^y$ and $\tilde{p}_i^m$ are the relative prices of gross output and intermediate inputs of industry i in relation to the GDP deflator, defined as $\tilde{p}_i^y = p_i^y / P^v$ and $\tilde{p}_i^m = p_i^m / P^v$.

Equation (1) shows that real GDP can be expressed as the weighted sum of the gross output quantities of its constituent industries minus the weighted sum of industry intermediate input quantities. The weights are the relative prices of gross outputs and intermediate inputs, respectively. Because the weights for each industry are the relative prices, they reflect the economic significance of the industry relative to other industries in creating economic value and thus income/wealth.

[10]For example, Jorgenson *et al.* (1987) and Jorgenson (2004).
[11]The GDP deflator is an implicit deflator, calculated as the ratio of nominal GDP to real GDP.

According to the formulation, if the gross output price is higher and the intermediate input price is lower, the industry will create more value and contribute more to real GDP. In this context, industry contribution to real GDP is closer to a value/wealth concept than the traditional "physical" concept. It is consistent with real GDP in the chained-Fisher index, which values an industry output more when its price rises and less when its price falls.

Let $\dot{V}^r_{i,s\to t}$ be real GDP growth from year s to year t, where $t > s$. It can then be decomposed into industry growth components:

$$
\begin{aligned}
(2)\quad \dot{V}^r_{s\to t} &\equiv \frac{V^r_t - V^r_s}{V^r_s} = \frac{1}{V^r_s}\sum_i \left[\left(\tilde{p}^y_{it} y^r_{it} - \tilde{p}^y_{is} y^r_{is}\right) - \left(\tilde{p}^m_{it} m^r_{it} - \tilde{p}^m_{is} m^r_{is}\right)\right] \\
&= \frac{1}{V^r_s}\sum_i \left[\tilde{p}^y_{is}\left(y^r_{it} - y^r_{is}\right) + \left(\tilde{p}^y_{it} - \tilde{p}^y_{is}\right)\left(y^r_{it} - y^r_{is}\right) + \left(\tilde{p}^y_{it} - \tilde{p}^y_{is}\right) y^r_{is}\right] \\
&\quad - \frac{1}{V^r_s}\sum_i \left[\tilde{p}^m_{is}\left(m^r_{it} - m^r_{is}\right) + \left(\tilde{p}^m_{it} - \tilde{p}^m_{is}\right)\left(m^r_{it} - m^r_{is}\right) + \left(\tilde{p}^m_{it} - \tilde{p}^m_{is}\right) m^r_{is}\right] \\
&= \sum_i \frac{\tilde{p}^y_{is} y^r_{is}}{V^r_s}\left(\frac{y^r_{it} - y^r_{is}}{y^r_{is}} + \frac{\tilde{p}^y_{it} - \tilde{p}^y_{is}}{\tilde{p}^y_{is}} + \frac{y^r_{it} - y^r_{is}}{y^r_{is}}\frac{\tilde{p}^y_{it} - \tilde{p}^y_{is}}{\tilde{p}^y_{is}}\right) \\
&\quad - \sum_i \frac{\tilde{p}^m_{is} m^r_{is}}{V^r_s}\left(\frac{m^r_{it} - m^r_{is}}{m^r_{is}} + \frac{\tilde{p}^m_{it} - \tilde{p}^m_{is}}{\tilde{p}^m_{is}} + \frac{m^r_{it} - m^r_{is}}{m^r_{is}}\frac{\tilde{p}^m_{it} - \tilde{p}^m_{is}}{\tilde{p}^m_{is}}\right) \\
&= \sum_i \left[\frac{y_{is}}{V_s}\left(\dot{y}^r_{i,s\to t} + \dot{\tilde{p}}^y_{i,s\to t} + \dot{y}^r_{i,s\to t}\dot{\tilde{p}}^y_{i,s\to t}\right) - \frac{m_{is}}{V_s}\left(\dot{m}^r_{i,s\to t} + \dot{\tilde{p}}^m_{i,s\to t} + \dot{m}^r_{i,s\to t}\dot{\tilde{p}}^m_{i,s\to t}\right)\right] \\
&= \sum_i \left[w^y_{is}\left(\dot{y}^r_{i,s\to t} + \dot{\tilde{p}}^y_{i,s\to t} + \dot{y}^r_{i,s\to t}\dot{\tilde{p}}^y_{i,s\to t}\right) - w^m_{is}\left(\dot{m}^r_{i,s\to t} + \dot{\tilde{p}}^m_{i,s\to t} + \dot{m}^r_{i,s\to t}\dot{\tilde{p}}^m_{i,s\to t}\right)\right],
\end{aligned}
$$

where $w^y_{is} = \frac{y_{is}}{V_s}$, $w^m_{is} = \frac{m_{is}}{V_s}$, and $\dot{y}^r_{i,s\to t}$ is the growth rate of y^r_i over the period from s to t (the same definition applying to other growth variables).

Equation (2) shows that each industry contributes to real GDP growth through an increase in real gross output or a rise in relative gross output price, which is offset by an increase in the use of intermediate inputs or a rise in the relative price of intermediate inputs. Thus, industry contribution depends on the value created by an industry by transforming intermediate inputs, which is determined by both quantity and price. One industry that produces products with improved prices will generate more value added than another industry that produces products with falling prices. For each industry, the contribution associated with gross output is weighted by the ratio of the industry nominal gross output to nominal GDP at the onset. The weights are analogous to the "Domar weights" that are used to aggregate industry multifactor productivity growth calculated based on the gross output concept.[12] Similarly, an industry's offsetting effect associated with intermediate inputs is weighted by the ratio of the industry nominal intermediate inputs to nominal GDP at the onset.

[12]Domar weights were originated by Domar (1961). They are the ratios of industry's current dollar gross output divided by aggregate value added in current dollars. The weights sum to more than one, reflecting the integration across industries. They have been widely used to aggregate gross output-based multifactor productivity at the industry level to the business sector or the economy level.

Alternatively, the contribution of industry i to real GDP growth over the period from s to t can be written as

$$(3) \qquad CPC_i^V = \left(w_{is}^y \dot{y}_{i,s\to t}^r - w_{is}^m \dot{m}_{i,s\to t}^r\right) + \left(w_{is}^y \dot{\tilde{p}}_{i,s\to t}^y - w_{is}^m \dot{\tilde{p}}_{i,s\to t}^m\right) + \left(w_{is}^y \dot{y}_{i,s\to t}^r \dot{\tilde{p}}_{i,s\to t}^y - w_{is}^m \dot{m}_{i,s\to t}^r \dot{\tilde{p}}_{i,s\to t}^m\right).$$

The first two terms on the right-hand side are called the *pure quantity effect* and the *pure price effect* as they measure separately the contributions of growth in quantity and a rise in relative price. These terms suggest that an increase in outsourcing/offshoring activities will not necessarily boost real GDP growth, but the use of cheaper intermediate inputs will certainly make a positive contribution. The third term is the interaction of the first two effects associated with gross output minus the interaction of the first two effects associated with intermediate inputs. The interaction effects occur because the change in relative price applies not only to the initial quantity but also to the change in quantity. However, the interaction term, which is a second-order effect, tends to be relatively small.

The above decomposition technique has several desirable properties. First, it is consistent with real GDP in the chained-Fisher index. Besides contributing to GDP growth through a change in output quantity, an industry also contributes positively (negatively) to real GDP growth when its relative output price rises (falls). Thus, it allows one to identify the sources of each industry's contribution to real GDP growth: the quantity effect or the price effect. Second, the axiomatically-derived decomposition and the outcome based on the economic approach advanced by Diewert (2002) are identical in the first-order effects, and importantly, besides the quantity effect, both call for the price effect to be part of an industry's contribution to the aggregate measure (see the proof in the Appendix). Third, it is additive for any long period as it is not necessary for year s and t to be adjacent. Fourth, the decomposition is base-year invariant because all variables in question are either initial nominal output/input shares or growth rates. And finally, the decomposition allows one to discuss the impact of the change in the use of intermediate inputs (outsourcing) on economic growth. For each industry, the pure quantity and price effects are net outcomes after impacts associated with the use of intermediate inputs.

There are different ways to decompose real GDP into industry contribution components. The features above are desirable and important for estimating and understanding industry contributions to real GDP growth. The first and third properties distinguish our decomposition technique from the traditional one used by Statistics Canada and the U.S. Bureau of Economic Analysis (BEA) to estimate industry contributions as a percentage change in real GDP.[13] The traditional decomposition technique suppresses the price effect by using a Fisher formula that averages prices over a period. As a result, it captures the quantity effect from the rise or fall in real output and ignores the price effect. Also, it is additive only for a period with two consecutive years.

[13]See Chevalier (2003) for Statistics Canada and Strassner *et al.* (2005) for the BEA.

The change in quantity and price of a product in a competitive market is determined by a change in demand or supply conditions. Given demand conditions, technological progress, or a reduction in input cost will cause a positive shift (downward) in the supply curve of an industry. This leads to an increase in output and a decrease in price. The opposite is true when the supply curve shifts upward due, for example, to a decline in production efficiency or an increase in input cost. Similarly, when there is a change in consumers' tastes and incomes or in external forces (e.g., international trade), the demand for the product will change. Given supply conditions, an increase in demand (a positive upward shift in the demand curve) for an industry's output will lead to an increase in both its quantity and price, and the opposite is true for a decrease in demand.

Over a given period, an industry's output and its contribution to real GDP growth are influenced in a complex way by changes in both demand and supply conditions. If an industry in a competitive product market experiences a positive shift in demand and supply, it will lead to an increase in its output. However, the net effect on price will depend on the relative strength of the two shifts. If the demand shift is stronger, the price will increase; if the supply shift is stronger, the price will decline. Similarly, if the industry experiences a negative shift in both demand and supply, output will decrease, but the net effect on price will again depend on the strength of one shift against the other. In the remaining two possibilities, where the shifts move in opposite directions, the effect on price can be determined, but the effect on quantity depends on the relative strength of the shifts in demand and supply. Because it is difficult to untangle effects from demand and supply shifts in a given period, this paper only addresses the *net* shift experienced by each industry.

To facilitate a discussion of demand and supply conditions and their contributions to economic growth, this paper will assign industries to four different groups according to the signs of the pure *gross output* quantity effect and the pure *gross output* price effect: positive or negative net demand shift (demand pull) and positive or negative net supply shift (supply push).[14] The four possible net shifts are shown in Table B.1 in the Appendix. As shown in Section 3, an industry most likely experiences either a positive net demand shift or a positive net supply shift. However, a few industries in both Canada and the United States experienced negative net demand shifts, especially manufacturing industries in the post-2000 period. A negative net supply shift is rare, but it did happen to the non-metallic mineral product manufacturing and basic and fabricated metal manufacturing industries in the United States in the post-2000 period.

2.2. *Industry Contribution to Aggregate Labour Productivity Growth*

As discussed earlier, unequal demand and supply shifts imply uneven changes in output and price. This also leads to a reallocation of production resources across

[14]This paper does not identify the size of supply and demand shifts, and only deals with the direction of the net shift.

industries. Do those changes affect aggregate labor productivity growth?[15] This section extends the decomposition technique for real GDP growth to estimate industry contribution to aggregate labor productivity growth. Thus, like the decomposition technique for real GDP growth, the decomposition technique for aggregate labor productivity growth is based on the gross output concept for industry output.

By definition, aggregate labor productivity is defined as real GDP per hour worked. Let X^r and H be aggregate labor productivity and total hours worked in the business sector. The aggregate labor productivity can then be decomposed into its industry components:

$$(4) \qquad \begin{aligned} X^r &= \frac{V^r}{H} = \frac{V}{P^V H} = \frac{Y-M}{P^V H} = \frac{\sum_i (y_i - m_i)}{P^V H} \\ &= \sum_i \left(\frac{p_i^y y_i^r - p_i^m m_i^r}{P^V H} \right) = \sum_i \left(\frac{p_i^y h_i x_i^y - p_i^m h_i x_i^m}{P^V H} \right) \\ &= \sum_i \frac{h_i}{H} \left(\tilde{p}_i^y x_i^y - \tilde{p}_i^m x_i^m \right) = \sum_i l_i \left(\tilde{p}_i^y x_i^y - \tilde{p}_i^m x_i^m \right) \\ &= \sum_i \left(\tilde{s}_i^y x_i^y - \tilde{s}_i^m x_i^m \right), \end{aligned}$$

where:

h_i is total hours worked for industry i;

x_i^y and x_i^m are real gross output per hour worked (or gross output labor productivity) and real intermediate input per hour worked (intermediate input intensity) for industry i, respectively;

$\tilde{s}_i^y = \tilde{p}_i^y l_i$ is the gross output relative size of industry i, equal to the product of the industry's labor input share ($l_i = h_i/H$) and its relative gross output price $(\tilde{p}_i^y)$; and

$\tilde{s}_i^m = \tilde{p}_i^m l_i$ is the intermediate input relative size of industry i, equal to the product of the industry's labor input share ($l_i = h_i/H$) and its relative intermediate input price $(\tilde{p}_i^m)$.

With this formulation, the aggregate labor productivity level equals the weighted industry gross output per hour worked minus the weighted industry intermediate inputs per hour worked. The weights are their corresponding relative sizes. The relative size of an industry for output (or intermediate input) is defined as the product of the hours worked share and the relative output (or intermediate input) price. Thus, the "size" of an industry in the new formulation for productivity contribution represents the economic importance of the industry by reflecting not only its labor share but also the "economic significance" of the industry in creating value. The formulation departs fundamentally from traditional

[15]This paper studies labor productivity, not multifactor productivity (MFP), for three reasons. First, aggregate labor productivity growth (instead of MFP growth) is regularly published by national statistical agencies to indicate countries' overall economic performance. Second, labor productivity is directly linked to GDP per capita, commonly used as an indicator of the level of the standard of living. Third, capital input is required to estimate MFP, which is difficult to measure and often not comparable across countries (Tang *et al.*, 2010). Finally, and most importantly, labor productivity is more tractable in decomposition.

methods that only consider the relative size of an industry being labor share.[16] The introduction of relative price in weights implies that industry contribution to aggregate labor productivity reflects the economic value of industry output. This means that industry contribution here is more than the traditional pure "quantity" concept.[17] As aggregate labor productivity is the ratio of real GDP to total hours worked, capturing the effect from a change in relative output price is thus consistent with real GDP in the chained-Fisher index in that it values real industry output more when its price rises and less when its price falls.

Like real GDP growth, aggregate labor productivity growth between year s and t, where $t > s$, can be decomposed into industry growth components as:

$$
\begin{aligned}
(5)\quad \dot{X}^v_{s\to t} &\equiv \frac{X^v_t - X^v_s}{X^v_s} = \frac{1}{X^v_s}\sum_i \left[\left(\tilde{s}^y_{it}x^y_{it} - \tilde{s}^y_{is}x^y_{is}\right) - \left(\tilde{s}^m_{it}x^m_{it} - \tilde{s}^m_{is}x^m_{is}\right)\right] \\
&= \frac{1}{X^v_s}\sum_i \left[\tilde{s}^y_{is}\left(x^y_{it} - x^y_{is}\right) + \left(\tilde{s}^y_{it} - \tilde{s}^y_{is}\right)\left(x^y_{it} - x^y_{is}\right) + \left(\tilde{s}^y_{it} - \tilde{s}^y_{is}\right)x^y_{is}\right] \\
&\quad - \frac{1}{X^v_s}\sum_i \left[\tilde{s}^m_{is}\left(x^m_{it} - x^m_{is}\right) + \left(\tilde{s}^m_{it} - \tilde{s}^m_{is}\right)\left(x^m_{it} - x^m_{is}\right) + \left(\tilde{s}^m_{it} - \tilde{s}^m_{is}\right)x^m_{is}\right] \\
&= \sum_i \frac{\tilde{s}^y_{is}x^y_{is}}{X^v_s}\left(\frac{x^y_{it} - x^y_{is}}{x^y_{is}} + \frac{\tilde{s}^y_{it} - \tilde{s}^y_{is}}{\tilde{s}^y_{is}} + \frac{x^y_{it} - x^y_{is}}{x^y_{is}}\frac{\tilde{s}^y_{it} - \tilde{s}^y_{is}}{\tilde{s}^y_{is}}\right) \\
&\quad - \sum_i \frac{\tilde{s}^m_{is}x^m_{is}}{X^v_s}\left(\frac{x^m_{it} - x^m_{is}}{x^m_{is}} + \frac{\tilde{s}^m_{it} - \tilde{s}^m_{is}}{\tilde{s}^m_{is}} + \frac{x^m_{it} - x^m_{is}}{x^m_{is}}\frac{\tilde{s}^m_{it} - \tilde{s}^m_{is}}{\tilde{s}^m_{is}}\right) \\
&= \sum_i \left[\frac{y_{is}}{V_s}\left(\dot{x}^y_{i,s\to t} + \dot{\tilde{s}}^y_{i,s\to t} + \dot{x}^y_{i,s\to t}\dot{\tilde{s}}^y_{i,s\to t}\right) - \frac{m_{is}}{V_s}\left(\dot{x}^m_{i,s\to t} + \dot{\tilde{s}}^m_{i,s\to t} + \dot{x}^m_{i,s\to t}\dot{\tilde{s}}^m_{i,s\to t}\right)\right] \\
&= \sum_i \left[w^y_{is}\left(\dot{x}^y_{i,s\to t} + \dot{\tilde{s}}^y_{i,s\to t} + \dot{x}^y_{i,s\to t}\dot{\tilde{s}}^y_{i,s\to t}\right) - w^m_{is}\left(\dot{x}^m_{i,s\to t} + \dot{\tilde{s}}^m_{i,s\to t} + \dot{x}^m_{i,s\to t}\dot{\tilde{s}}^m_{i,s\to t}\right)\right].
\end{aligned}
$$

With this formulation, each industry contributes to aggregate labor productivity growth through an increase in its gross output labor productivity or a rise in its relative size associated with gross output. This is partly offset by an increase in intermediate input intensity and a rise in its relative size associated with intermediate inputs. Like the contributions of the industry to real GDP growth, the contributions of the industry associated with gross output are weighted by the ratio of the industry's nominal gross output to nominal GDP at the start. The contributions associated with intermediate inputs are weighted by the ratio of the industry's nominal intermediate inputs to nominal GDP at the onset. The weights are analogous to the "Domar weights" used to aggregate industry multifactor productivity growth calculated based on the gross output concept.

Alternatively, the contribution of an industry to aggregate labor productivity growth can be written as

[16]For example, Basu and Fernald (2002); Jorgenson and Stiroh (2000); Stiroh (2002); Jorgenson (2004); and Ho *et al.* (2004).

[17]In practice, due to data limitation on price, productivity measures often embody value. This is true even at the firm level. Because of the lack of firm-level deflators, the same industry deflators are often applied to both firms with high value products and those with lower value products.

$$(6) \qquad CPC_i^X = \left(w_{is}^y \dot{x}_{i,s\to t}^y - w_{is}^m \dot{x}_{i,s\to t}^m\right) + \left(w_{is}^y \dot{\tilde{s}}_{i,s\to t}^y - w_{is}^m \dot{\tilde{s}}_{i,s\to t}^m\right) + \left(w_{is}^y \dot{x}_{i,s\to t}^y \dot{\tilde{s}}_{i,s\to t}^y - w_{is}^m \dot{x}_{i,s\to t}^m \dot{\tilde{s}}_{i,s\to t}^m\right).$$

The three terms from left to right are the *pure productivity effect*, the *relative size effect*, and the interaction of the first two effects. The pure productivity effect captures an industry's contribution stemming from improvements in labor productivity of the industry. Similarly, the relative size effect reflects only the change in the relative size of the industry. The interaction term captures the effect of the change in relative size on the change in labor productivity. For example, an increase in hours worked share and/or relative price will apply not only to the initial labor productivity level but also to the change in labor productivity.

As in real GDP growth, for the discussion of demand and supply conditions and their contributions to aggregate labor productivity growth, this paper also assigns industries to four different groups according to the matrix in Table B.1 in the Appendix.

3. Empirical Results on Industry Contribution to Economic Growth

The decomposition techniques, equations (2) and (5), are applied to the business sector in Canada and the United States, using a comparable dataset on gross output, labor, and intermediate inputs for the two countries. The data for both Canada and the United States are from the World KLEMS databases, which were developed by Statistics Canada and Harvard University (i.e., Dale Jorgenson associates). For each country, the KLEMS database contains data on gross output, labor, and intermediate inputs, which are necessary data for our analyses. For both Canada and the United States, the data are analyzed for 29 industries (as listed in Table B.2 in the Appendix) covering the period 1981–2007.

The discussion of the results is primarily for the 1981–2007 period. However, the main results associated with the sub-periods (1981–95, 1995–2000, and 2000–07), which are reported in the Appendix, are also briefly discussed.

3.1. *Distribution of Industries with Net Supply/Demand Shifts*

During any period, different industries may experience different demand and supply shocks. We cannot measure and separate demand shocks from supply shocks, but we can observe the net shift for each industry. As discussed earlier, we can identify the net shift according to the signs of the change in gross output quantity effect and in gross output price effect.

Between 1981 and 2007, all industries in Canada experienced either a positive net supply shift or a positive net demand shift, except for textiles and leather, and coke and petroleum (Figure C.3 in the Appendix). Out of 29 industries, 18 underwent positive net supply shifts, with positive pure gross output quantity effects and negative pure gross output price effects. Nine industries underwent positive net demand shifts, with positive pure gross output quantity and positive pure gross output price effects. Coke and petroleum experienced a negative net supply shift with a small negative gross output effect and a small positive gross output price effect. Textiles and leather experienced a negative net demand shift with negative pure gross output quantity effects and negative pure gross output price effects. The reduced demand for made-in-Canada textiles and leather reflects the increased competition from emerging economies such as China. Some of the reduced demand reflects production activities that were moved overseas by multinationals in Canada to take advantage of low-cost labor.

However, the industry distribution with different net shifts changed over time, due to the changes in supply and demand conditions. Compared to the 1981–95 period, the economic boom in the late 1990s shifted the industry distribution to the left, with all industries experiencing a positive gross output quantity effect. But in the post-2000 period, the industry distribution was shifted back, further to the left, mainly due to a substantial appreciation of the Canadian dollar, economic growth slowdown in the United States, and increased competition from emerging economies. Many industries had negative gross output quantity effects. Most of those industries were manufacturing industries, including textiles and leather; wood; paper and printing; electrical and optical; and transport equipment.

The movements in three industries (transportation equipment, mining, and construction) over the three sub-periods were particularly interesting. These industries represented the changes in demand condition, driven by different forces. The transportation equipment manufacturing industry had the largest gross output effect from 1981 to 1995, and the effect became even greater during the 1995–2000 economic boom. But it declined substantially and became negative in the post-2000 period, together with a large negative gross output price effect. This occurred due to weak demand conditions, mainly originated in the United States, for transportation equipment made-in-Canada. The opposite was true for the mining sector and construction. The gross output quantity effect for construction was small and negative from 1981 to 1995, but the effect was strong and positive in the subsequent two sub-periods. In the post-2000 period, the gross output price effect was also strong and positive, reflecting strong demand for construction products/services in both the housing and mining sectors in Canada. For the mining sector, most of the change was in the gross output price effect, reflecting the change in commodity prices and demand for commodities from emerging economies. The price effect was the largest negative in 1981–95, and it turned to be the largest positive in 1995–2000 and 2000–07. It is interesting to note that the gross output quantity effect did not change much over the three periods. This may reflect the fact that the lead time for developing a mining project is long, and that it becomes more costly to extract resources as extraction activities are moving to lower quality deposits.

The movements in supply and demand shifts in the United States in 1981–2007 were similar to those in Canada. Out of 29 industries, 18 experienced positive net supply shifts, nine went through positive net demand shifts, and two faced negative net demand shift. Furthermore, the movement of the distribution of industries with different net shifts in the United States was similar to that in Canada, although the distribution for the United States was not pulled as far to the left as in Canada in 2000–07 (Figure C.4 in the Appendix). This reflected smaller negative demand shocks in the United States, especially in the manufacturing sector in the post-2000 period.[18]

3.2. *Empirical Results on Industry Contribution to Real GDP Growth*

Canada

Real GDP in Canada grew on average 2.9 percent per year over the whole 1981–2007 period (Table 1).[19] The growth rate accelerated from 2.5 percent per year during the 1981–95 sub-period to 4.4 percent per year during the 1995–2000 sub-period, but decelerated back to 2.6 percent per year in the post-2000 sub-period.

In terms of pure quantity effect, the single largest contribution to the growth came from output growth in real estate activities (0.37 percentage points), followed by wholesale trade (0.29 percentage points). However, the ranking can be different across sub-periods. From 1995 to 2000, the largest contributor was other business services (0.59 percentage points), followed by wholesale trade (0.42 percentage points).[20]

The pure price effects were relatively small in magnitude and they almost offset each other among the industries. For the whole 1981–2007 period, the largest positive pure price effect occurred in health and social work (0.09 percentage points), followed closely by mining (0.08 percentage points). For the 1981–95 sub-period, the industry with the largest pure price effect was real estate activities, followed by health and social work and then education. These positive pure price effects were almost offset by the largest negative pure price effect from mining over this sub-period. But, in 1995–2000 and 2000–04, mining was the largest contributor in pure price effect.

In terms of total industry contribution (which considers the pure quantity effect, the pure price effect, and the interaction term), real estate activities was the largest contributor (0.36 percentage points) for the whole 1981–2007 period, followed by financial intermediation (0.28 percentage points), and other business services (0.27 percentage points). For the 1981–95 sub-period, the largest contributor was real estate activities, followed by financial intermediation and health and social work (Figure C.5 in the Appendix). For the next two sub-periods, the largest contributor was mining, which was followed by other business services and financial intermediation in 1995–2000, and construction and financial intermediation in 2000–07.

For the whole sample period, the industry group with net supply shifts (mainly agriculture, manufacturing industries, and some service industries such as wholesale trade, retail trade, transportation and storage, post and telecommunications, and other business services) made a total contribution of 1.2 percentage points to real GDP growth, compared to 1.7 percentage points for the industry

[18]Larger negative demand shock in the Canadian manufacturing sector post-2000 also reflected the substantial appreciation of the Canadian dollar over this period (about 40 percent relative to the U.S. dollar).

[19]The reported figures are averages of annual rates, which are almost identical to the compounding growth rates.

[20]Industry contribution to real GDP growth for the three sub-periods is reported in Tables B.3a, B.3b, and B.3c in the Appendix.

TABLE 1

Industry Contributions to Real GDP Growth in the Canadian Business Sector (average annual percentage points, 1981–2007)

	Pure Quantity Effect			Pure Price Effect			Interaction				
Industry	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total	Total	Net Shift
Agriculture	0.14	0.09	0.04	–0.11	–0.05	–0.07	0.00	0.00	0.00	–0.02	S+
Mining	0.22	0.09	0.13	0.09	0.01	0.08	0.02	0.00	0.01	0.23	D+
Food, beverage, tobacco	0.12	0.10	0.02	–0.04	–0.07	0.03	0.00	0.00	0.00	0.05	S+
Textiles, leather	–0.02	–0.01	–0.01	–0.02	–0.02	0.00	0.00	0.00	0.00	–0.01	D–
Wood	0.11	0.07	0.04	–0.03	–0.02	–0.02	0.00	0.00	0.00	0.03	S+
Paper, printing	0.10	0.06	0.03	–0.03	–0.02	–0.01	0.00	0.00	0.00	0.03	S+
Coke, petroleum	–0.01	–0.01	0.01	0.00	–0.01	0.01	0.00	0.00	0.00	0.02	S–
Chemicals	0.12	0.07	0.05	–0.04	–0.01	–0.03	0.00	0.00	0.00	0.02	S+
Rubber, plastics	0.10	0.06	0.04	–0.02	–0.01	–0.01	0.00	0.00	0.00	0.03	S+
Non-metallic mineral	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	S+
Basic & fabricated metal	0.16	0.10	0.06	–0.04	–0.02	–0.02	0.01	0.00	0.00	0.05	S+
Machinery	0.06	0.04	0.02	–0.01	–0.01	–0.01	0.00	0.00	0.00	0.02	S+
Electrical & optical	0.17	0.12	0.05	–0.09	–0.06	–0.03	–0.01	0.00	0.00	0.01	S+
Transport equipment	0.51	0.40	0.11	–0.11	–0.08	–0.03	0.00	–0.01	0.00	0.08	S+
Manufacturing n.e.c.	0.06	0.04	0.02	–0.01	–0.01	0.00	0.00	0.00	0.00	0.02	S+
Utilities	0.10	0.04	0.06	0.01	0.00	0.02	0.00	0.00	0.00	0.07	D+
Construction	0.32	0.20	0.12	0.03	0.01	0.01	0.01	0.00	0.01	0.14	D+
Sale & repair of motor vehicles	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	S+
Wholesale trade	0.47	0.18	0.29	–0.09	–0.01	–0.08	–0.01	0.00	0.00	0.20	S+
Retail trade	0.40	0.15	0.25	–0.07	–0.02	–0.06	0.00	0.00	0.00	0.19	S+
Hotels and restaurants	0.10	0.07	0.03	0.03	0.01	0.02	0.00	0.00	0.00	0.06	D+
Transport and storage	0.27	0.14	0.13	–0.04	–0.01	–0.03	0.00	0.00	0.00	0.10	S+
Post and telecommunications	0.23	0.09	0.14	–0.06	0.00	–0.06	–0.01	0.00	0.00	0.08	S+
Financial intermediation	0.44	0.20	0.25	0.07	0.04	0.03	0.00	0.00	0.00	0.28	D+
Real estate activities	0.47	0.10	0.37	0.01	0.02	–0.01	0.00	0.00	0.00	0.36	D+
Other business service	0.49	0.22	0.27	–0.01	–0.01	0.00	0.00	0.00	0.00	0.27	S+
Education	0.11	0.03	0.08	0.04	0.00	0.04	0.00	0.00	0.00	0.12	D+
Health and social work	0.22	0.11	0.11	0.08	–0.01	0.09	0.00	0.00	0.00	0.20	D+
Other services	0.35	0.17	0.18	0.05	0.00	0.06	0.00	0.00	0.00	0.24	D+
Supply-driven industries	3.53	1.93	1.60	–0.83	–0.44	–0.39	–0.02	–0.01	–0.01	1.20	S+
Demand-driven industries	2.31	1.00	1.31	0.40	0.06	0.34	0.03	0.00	0.03	1.68	D+
Total	5.85	2.93	2.92	–0.43	–0.38	–0.05	0.01	–0.01	0.02	2.89	

group with net demand shifts (mining, utilities, construction, hotels and restaurants, financial intermediation, real estate activities, education, health and social work, and other services). Clearly, over the longer term, real GDP growth was dominated by industries with net demand shifts. This was true for the first two sub-periods, 1981–95 and 2000–07. For the 1995–2000 period, however, real GDP growth was largely driven by industries with net supply shifts.

It is interesting to note that the transportation equipment manufacturing industry was one of the industries with the largest gross output quantity effect in either 1981–95 or 1995–2000. But the effect was largely offset by the quantity effect due to an increase in the use of intermediate inputs. Similarly, the large gross output quantity effect in 1981–2007 for construction, wholesale trade, retail trade, financial intermediation, and other business services also reflects the increased use of intermediate inputs.

Mining was highly volatile in price. It became the largest contributor to real GDP growth in 1995–2007, after being the largest drag to real GDP growth in 1981–95, mainly because of the change in price effect.

The United States

Real GDP in the business sector in the United States grew by 3.1 percent per year over the period 1981–2007 (Table 2), slightly higher than the 2.9 percent per year for Canada. The growth rate was higher in the United States (3.0 percent) than in Canada (2.5 percent) in 1981–95, about the same (4.4 percent) in 1995–2000, and lower (2.3 percent for the United States versus 2.6 percent for Canada) in 2000–07.

In terms of pure quantity effect, the single largest contribution to real GDP growth in the United States in 1981–2007 was from other business services (0.60 percentage points), followed by electrical and optical products manufacturing (0.36 percentage points).[21] The largest positive pure price effect occurred in health and social work (0.17 percentage points), followed by real estate activities and construction (0.12 percentage points each). In terms of total industry contribution, the largest contributor was other business services (0.66 percentage points), followed by real estate activities (0.43 percentage points). It is important to note that the total contribution from the electrical and optical products manufacturing industry was very small since its large quantity effect was mostly offset by its negative price effect.

Over the whole sample period, there was a large difference in industry contribution to real GDP growth between Canada and the United States. Mining, basic and fabricated metals, and wholesale and retail trade contributed more in Canada than in the United States. In contrast, other business services, health and social work, education, financial intermediation, and real estate activities contributed more in the United States than in Canada. Industries with net demand shifts and industries with net supply shifts contributed 2.43 and 0.65 percentage points, respectively, to real GDP growth in the United States. This compared to 1.68 and 1.20 percentage points in Canada. In the post-2000 period, real GDP grew faster in Canada (2.6 percent per year) than in the United States (2.3 percent per year) (Figure C.6 in the Appendix). The growth in Canada was largely supported by

[21]Industry contribution to real GDP growth in the United States for the three sub-periods is reported in Tables B.4a, B.4b, and B.4c in the Appendix.

TABLE 2

Industry Contributions to Real GDP Growth in the U.S. Business Sector (average annual percentage points, 1981–2007)

Industry	Pure Quantity Effect			Pure Price Effect			Interaction			Total	Net Shift
	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total		
Agriculture	0.06	0.01	0.05	–0.07	–0.03	–0.04	0.00	0.00	0.00	0.00	S+
Mining	0.00	–0.02	0.02	–0.04	–0.01	–0.03	0.01	0.00	0.00	–0.01	D–
Food, beverage, tobacco	0.11	0.09	0.02	–0.06	–0.06	0.00	0.00	0.00	0.00	0.02	S+
Textiles, leather	–0.01	–0.02	0.00	–0.04	–0.02	–0.02	0.00	0.00	0.00	–0.02	D–
Wood	0.02	0.01	0.01	–0.01	–0.01	0.00	0.00	0.00	0.00	0.01	S+
Paper, printing	0.07	0.06	0.01	0.00	–0.02	0.02	0.00	0.00	0.00	0.03	D+
Coke, petroleum	0.03	0.00	0.03	–0.05	–0.03	–0.02	0.01	0.01	–0.01	0.01	S+
Chemicals	0.07	0.04	0.04	0.00	–0.02	0.02	0.00	0.00	0.00	0.06	S+
Rubber, plastics	0.07	0.04	0.02	–0.02	–0.01	–0.01	0.00	0.00	0.00	0.01	S+
Non-metallic mineral	0.02	0.01	0.01	–0.01	–0.01	0.00	0.00	0.00	0.00	0.01	S+
Basic & fabricated metal	0.01	0.02	–0.01	–0.04	–0.04	–0.01	0.00	0.00	0.00	–0.02	S+
Machinery	0.00	0.02	–0.01	–0.02	–0.02	0.00	0.00	0.00	0.00	–0.01	S+
Electrical & optical	0.59	0.24	0.36	–0.44	–0.16	–0.28	–0.04	–0.01	–0.03	0.05	S+
Transport equipment	0.23	0.16	0.07	–0.09	–0.07	–0.03	0.00	0.00	0.00	0.04	S+
Manufacturing n.e.c.	0.03	0.02	0.01	–0.01	–0.01	0.00	0.00	0.00	0.00	0.01	S+
Utilities	0.01	–0.02	0.03	0.00	–0.03	0.03	0.00	0.00	0.00	0.06	S+
Construction	0.19	0.15	0.04	0.08	–0.03	0.12	0.00	0.00	0.00	0.16	D+
Sale & repair of motor vehicles	0.09	0.03	0.06	–0.03	0.00	–0.03	0.00	0.00	0.00	0.03	S+
Wholesale trade	0.39	0.10	0.29	–0.17	–0.01	–0.16	–0.01	0.00	–0.01	0.12	S+
Retail trade	0.39	0.14	0.25	–0.13	0.00	–0.12	0.00	0.00	0.00	0.13	S+
Hotels and restaurants	0.15	0.09	0.07	0.02	–0.01	0.03	0.00	0.00	0.00	0.09	D+
Transport and storage	0.20	0.06	0.14	–0.07	–0.01	–0.06	0.00	0.00	0.00	0.07	S+
Post and telecommunications	0.23	0.12	0.11	–0.07	–0.02	–0.05	–0.01	0.00	0.00	0.05	S+
Financial intermediation	0.67	0.37	0.30	0.00	–0.04	0.04	0.00	0.00	0.00	0.35	D+
Real estate activities	0.47	0.16	0.30	0.15	0.02	0.12	0.00	0.00	0.01	0.43	D+
Other business service	1.05	0.45	0.60	0.04	–0.01	0.06	0.00	0.00	0.00	0.66	D+
Education	0.24	0.14	0.10	0.09	0.00	0.10	0.00	0.00	0.00	0.20	D+
Health and social work	0.39	0.22	0.17	0.17	0.00	0.17	0.01	0.00	0.00	0.35	D+
Other services	0.28	0.18	0.11	0.06	–0.01	0.07	0.00	0.00	0.00	0.17	D+
Supply-driven industries	2.56	1.09	1.47	–1.30	–0.54	–0.76	–0.07	0.00	–0.07	0.65	S+
Demand-driven industries	3.49	1.78	1.71	0.53	–0.13	0.66	0.02	–0.01	0.03	2.40	D+
Total	6.05	2.87	3.18	–0.77	–0.67	–0.10	–0.04	0.00	–0.04	3.05	

mining, construction, financial intermediation, and retail and wholesale trade, which was offset by transportation equipment and some other manufacturing industries. In contrast, in the United States, the largest contributors were other business services, health and social work, real estate activities, and financial intermediation. Several manufacturing industries were also a drag to real GDP growth in the United States, but they were to a lesser extent relative to the situation in Canada.

The total pure price effect for supply-driven industries was much stronger in the United States than in Canada. The difference was partly due to the fact that the manufacturing sector in Canada was concentrated relatively more in resource manufacturing, while in the United States it was concentrated relatively more in high-tech manufacturing (see hours worked shares in Tables B.5 and B.6 in the Appendix). It was also due to faster multifactor productivity (MFP) growth in some industries (e.g., information technology manufacturing industries) in the United States than was observed in Canada (Ho *et al.*, 2004).[22] This led to a larger decline in output price in the United States in those industries. For instance, the real gross output price for the electrical and optical products declined by 81.3 percent in the United States over the 1981–2007 sample period, while in Canada it declined by 45.5 percent.

In general, demand-shifts were also stronger in the United States than in Canada in 1981–2007. The effect from gross output growth for industries with net demand shifts was greater in the United States than in Canada as was the effect from the increase in gross output price. For the industries with net demand shifts, the total contribution to aggregate output growth in the United States (2.40 percentage points) was much larger than in Canada (1.68 percentage points). Much of the difference was associated with a larger increase in the real gross output prices of these industries in the United States. In 1981–2007, the real gross output price of real estate activities increased by 37.5 percent in the United States compared to almost zero in Canada (Tables B.5 and B.6 in the Appendix). The output prices of construction and other business services also increased much faster in the United States than in Canada.

A Comparison with the Jorgenson Methodology

The methodology developed by Jorgenson *et al.* (2003) (hereafter the Jorgenson methodology) has been widely used to study industry contribution to real GDP growth. It is a bottom-up approach. Aggregate real value added (or real GDP) is calculated as a translog index over industry real value added $\left(v_i^r\right)$,

$$\Delta \ln V_t^r = \sum\nolimits_i \bar{w}_{i,t} \Delta \ln v_{i,t}^r, \tag{7}$$

where $\Delta \ln V_t^r = \ln\left(V_t^r\right) - \ln\left(V_{t-1}^r\right)$, $\Delta \ln v_{i,t}^r = \ln\left(v_{i,t}^r\right) - \ln\left(v_{i,t-1}^r\right)$ and $\bar{w}_i$ is the two-period average share of industry nominal value added in aggregate nominal

[22]Measured MFP is often used as an indicator for technological progress, despite that it may capture the effect from other factors such as business cycles, economies of scale, and unmeasured inputs.

TABLE 3

Industry Total Contribution to Real GDP Growth: A Comparison of Current Methodology and Jorgenson *et al.* (2003) (average annual percentage points)

	1995–2000				2000–07			
	Canada		United States		Canada		United States	
Industry	TW	JOR	TW	JOR	TW	JOR	TW	JOR
Agriculture	–0.01	0.07	0.03	0.08	–0.04	0.02	0.05	0.03
Mining	0.68	0.09	0.09	–0.04	0.58	0.12	0.16	–0.04
Food, beverage, tobacco	0.06	0.04	0.02	–0.05	0.02	0.01	–0.02	0.00
Textiles, leather	0.04	0.03	–0.02	–0.01	–0.06	–0.05	–0.03	–0.02
Wood	0.10	0.09	0.01	0.01	–0.06	0.02	–0.01	0.00
Paper, printing	0.01	0.09	0.05	0.04	–0.09	–0.01	–0.05	–0.03
Coke, petroleum	0.02	0.01	0.01	0.04	0.05	0.01	0.05	–0.08
Chemicals	–0.04	0.08	0.02	0.01	–0.03	0.01	0.07	0.05
Rubber, plastics	0.07	0.08	0.03	0.04	–0.01	0.01	–0.02	–0.01
Non-metallic mineral	0.03	0.04	0.02	0.02	0.01	0.02	0.00	0.00
Basic & fabricated metal	0.20	0.20	0.04	0.05	0.01	0.01	–0.01	–0.05
Machinery	0.08	0.06	0.04	0.00	–0.01	0.01	–0.01	0.01
Electrical & optical	0.14	0.21	0.15	0.66	–0.10	–0.09	–0.10	0.16
Transport equipment	0.24	0.21	0.07	0.05	–0.19	–0.02	–0.03	0.05
Manufacturing n.e.c.	0.09	0.10	0.03	0.02	0.00	–0.01	–0.01	0.00
Utilities	–0.01	0.00	–0.04	0.03	0.02	0.06	0.06	0.04
Construction	0.23	0.23	0.33	0.15	0.47	0.29	0.12	–0.13
Sale & repair of motor vehicles	0.01	0.01	0.04	0.08	0.01	0.01	0.02	0.06
Wholesale trade	0.26	0.40	0.20	0.49	0.21	0.27	0.10	0.14
Retail trade	0.32	0.32	0.15	0.33	0.25	0.29	0.08	0.24
Hotels and restaurants	0.07	0.09	0.16	0.09	0.04	0.03	0.08	0.06
Transport and storage	0.16	0.19	0.15	0.15	0.10	0.10	0.05	0.10
Post and telecommunications	0.07	0.18	0.10	0.18	0.09	0.12	0.00	0.13
Financial intermediation	0.37	0.32	0.54	0.54	0.29	0.27	0.25	0.32
Real estate activities	0.24	0.34	0.50	0.34	0.20	0.34	0.36	0.36
Other business service	0.55	0.57	1.04	0.85	0.26	0.29	0.43	0.56
Education	0.01	0.05	0.21	0.11	0.12	0.11	0.18	0.05
Health and social work	0.13	0.06	0.23	0.10	0.20	0.11	0.37	0.30
Other services	0.31	0.22	0.19	0.05	0.27	0.24	0.11	0.05
Supply-driven industries	2.35	2.95	1.49	3.07	0.49	1.07	0.73	1.37
Demand-driven industries	2.08	1.42	2.93	1.36	2.14	1.51	1.53	1.01
Real GDP growth*	4.43	4.38	4.42	4.43	2.62	2.58	2.26	2.38

Note: TW – the methodology based on current study; JOR – the methodology based on Jorgenson *et al.* (2003).

*Real GDP growth under "JOR" is slightly different from that under "TW" because the former is calculated based on the bottom-up approach in Jorgenson *et al.* (2003) while the latter is calculated from top-down.

value added. The real value added of industry i is defined as an index of gross output less intermediate inputs

$$\Delta \ln v_{i,t}^{r} = \frac{1}{\bar{\phi}_{i,t}}\left[\Delta \ln y_{i,t}^{r} - \left(1-\bar{\phi}_{i,t}\right)\Delta \ln m_{i,t}^{r}\right], \tag{8}$$

and $\bar{\phi}_{i,t}$ is the two-period average share of nominal value added in nominal gross output in industry i.

By definition, an industry contribution to real GDP growth would be $\bar{w}_{i,t}\Delta \ln v_{i,t}^{r}$. The comparison of the industry contribution to real GDP growth based on our methodology with those based on the Jorgenson methodology for the sub-periods 1995–2000 and 2000–07 is reported in Table 3.

The pattern is very clear. Compared to the Jorgenson methodology, ours clearly favors industries that are driven by demand shifts or with improved real output prices. For instance, in the post-2000 period, we show that demand-driven industries contributed 82 percent of real GDP growth in Canada while it was 59 percent when the Jorgenson methodology was used. Similarly, for the United States, we show that the contribution from demand-driven industries was 68 percent compared to 42 percent when the Jorgenson methodology was used.

Notably, in the second half of the 1990s, the mining sector, mainly driven by improved demand conditions, contributed 0.68 percentage points of real GDP growth in Canada compared to only 0.09 percentage points based on the Jorgenson methodology. On the other hand, in the same period, our results show that the electrical and optical product manufacturing industry, which is largely driven by improved supply condition, contributed 0.15 percentage points to real GDP growth in the United States, compared to 0.66 percentage points based on the Jorgenson methodology.

3.3. *Empirical Results on Industry Contribution to Aggregate Labour Productivity Growth*

The decomposition technique, equation (5), is applied to aggregate labor productivity growth in the business sector in both Canada and the United States, based on the same data as used for decomposing real GDP growth.

Canada

Over the 1981–2007 period, labor productivity, which is defined as real GDP per hour worked, increased by 1.4 percent per year. The growth rate was 1.3 percent per year in 1981–95, but it accelerated to 2.0 percent per year in the second half of 1990 and decelerated to 1.1 percent per year in the post-2000 period.

In 1981–2007, labor productivity growth was mainly due to the pure productivity effect, which was partly offset by the relative size effect (Table 4).[23] In terms of the pure productivity effect, real estate activities was the largest contributor to aggregate labor productivity growth (0.47 percentage points), followed by wholesale trade (0.19 percentage points) and retail trade (0.15 percentage points). The effect from real estate activities was largely from the 1981–95 sub-period. For all industries, the pure productivity effect in 2000–07 was smaller compared to the previous two sub-periods, 1981–95 and 1995–2000.

In terms of the relative size effect, the contribution from some industries was notable, although it is small relative to the pure productivity effect. Over the 1981–2007 sample period, the largest contributors were mining and other services (0.17 percentage points each), followed by other business services (0.12 percentage points). The industries with the largest negative contributions were real estate activities (–0.22 percentage points) and agriculture (–0.14 percentage points). However, the relative size effect can be substantially different for some industries across different sub-periods. For instance, in the case of mining, the industry

[23]Industry contribution to aggregate labor productivity growth in Canada for the three sub-periods is reported in Tables B.7a, B.7b, and B.7c in the Appendix.

TABLE 4

Industry Contributions to Real GDP per hour Growth in the Canadian Business Sector (average annual percentage points, 1981–2007)

	Pure Productivity Effect			Relative Size Effect			Interaction				
Industry	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total	Total	Net Shift
Agriculture	0.22	0.15	0.08	–0.29	–0.15	–0.14	–0.02	–0.01	–0.01	–0.07	S+
Mining	0.04	0.03	0.01	0.20	0.04	0.17	–0.05	–0.01	–0.04	0.14	D+
Food, beverage, tobacco	0.17	0.14	0.03	–0.21	–0.19	–0.02	–0.01	–0.01	0.00	0.01	S+
Textiles, leather	0.04	0.03	0.01	–0.11	–0.07	–0.04	0.00	0.00	0.00	–0.03	D–
Wood	0.13	0.08	0.05	–0.09	–0.06	–0.03	–0.01	–0.01	–0.01	0.01	S+
Paper, printing	0.10	0.07	0.04	–0.12	–0.08	–0.04	0.00	0.00	0.00	–0.01	S+
Coke, petroleum	0.05	0.04	0.01	–0.07	–0.08	0.01	–0.04	–0.03	0.00	0.02	S–
Chemicals	0.13	0.07	0.06	–0.11	–0.06	–0.05	–0.01	0.00	0.00	0.00	S+
Rubber, plastics	0.05	0.03	0.02	–0.01	0.00	0.00	0.00	0.00	0.00	0.02	S+
Non-metallic mineral	0.02	0.01	0.01	–0.02	–0.01	–0.01	0.00	0.00	0.00	0.00	S+
Basic & fabricated metal	0.18	0.11	0.06	–0.15	–0.10	–0.05	–0.01	–0.01	0.00	0.01	S+
Machinery	0.06	0.03	0.02	–0.05	–0.03	–0.02	0.00	0.00	0.00	0.00	S+
Electrical & optical	0.19	0.13	0.05	–0.17	–0.11	–0.06	0.00	0.00	0.00	–0.01	S+
Transport equipment	0.47	0.37	0.09	–0.24	–0.18	–0.06	–0.01	–0.01	0.00	0.04	S+
Manufacturing n.e.c.	0.03	0.02	0.01	–0.02	–0.02	0.00	0.00	0.00	0.00	0.01	S+
Utilities	0.08	0.03	0.04	–0.02	–0.01	–0.01	–0.01	0.00	–0.01	0.03	D+
Construction	0.07	0.04	0.03	0.06	0.03	0.02	–0.01	0.00	0.00	0.05	D+
Sale & repair of motor vehicles	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	S+
Wholesale trade	0.31	0.12	0.19	–0.07	0.00	–0.07	–0.01	0.00	–0.01	0.12	S+
Retail trade	0.25	0.10	0.15	–0.06	–0.01	–0.05	–0.01	0.00	0.00	0.09	S+
Hotels and restaurants	0.01	0.03	–0.01	0.04	0.01	0.03	0.00	0.00	0.00	0.02	D+
Transport and storage	0.14	0.08	0.06	–0.04	–0.01	–0.03	–0.01	0.00	0.00	0.03	S+
Post and telecommunications	0.16	0.07	0.10	–0.06	0.00	–0.06	0.00	0.00	0.00	0.04	S+
Financial intermediation	0.22	0.09	0.12	0.13	0.07	0.07	–0.01	0.00	0.00	0.18	D+
Real estate activities	0.58	0.12	0.47	–0.24	–0.03	–0.22	–0.07	–0.01	–0.06	0.19	D+
Other business service	0.16	0.10	0.07	0.18	0.06	0.12	0.00	0.00	0.00	0.19	S+
Education	0.02	0.01	0.00	0.04	0.00	0.04	0.00	0.00	0.00	0.04	D+
Health and social work	0.08	0.08	0.00	0.11	0.00	0.11	0.00	0.00	0.00	0.11	D+
Other services	0.05	0.05	0.00	0.24	0.07	0.17	0.00	0.00	0.00	0.17	D+
Supply-driven industries	2.83	1.72	1.10	–1.61	–1.04	–0.56	–0.14	–0.09	–0.04	0.50	S+
Demand-driven industries	1.18	0.52	0.67	0.45	0.11	0.35	–0.15	–0.03	–0.12	0.89	D+
Total	4.01	2.24	1.77	–1.15	–0.94	–0.22	–0.29	–0.12	–0.16	1.39	

recorded –0.32 percentage points in 1981–95, but it was 0.58 and 0.86 percentage points in 1995–2000 and 2000–07, respectively.

In terms of the total effect across the whole 1981–2007 sample period, real estate activities and other business services were the largest contributors (0.19 percentage points each), followed closely by financial intermediation (0.18 percentage points) and other services (0.17 percentage points). However, the largest contributor alternates over time (Figure C.7 in the Appendix). In 1981–95, it was real estate activities, but for the next two sub-periods (1995–2000 and 2000–07), it was mining. The figure shows that the decline in aggregate labor productivity growth from the 1995–2000 period to the post-2000 period was mainly due to negative contributions from many manufacturing industries and other business services.

Interestingly, the total contribution of some industries was small or even negative for the whole sample period. For instance, the total contribution of agriculture over 1981–2007 was –0.07 percentage points. This was because this industry's positive pure productivity effect was more than offset by the negative effect from a decline in its relative size, which mainly reflected declines in its share of hours worked and in its relative output price (Table B.5 in the Appendix).

The net supply shift industry group—consisting of agriculture, all manufacturing industries (except textiles and leather), wholesale trade, retail trade, transport and storage, and post and telecommunications—contributed 0.50 percentage points to aggregate labor productivity growth over the whole sample period (Table 4). All of these supply-driven industries experienced no significant improvement or a decline in relative size. This translated into an overall contribution of –0.56 percentage points. The decline in relative size reflected a decline in relative output price and for some industries a decline in the share of hours worked (Table B.5 in the Appendix).

The industry group with net demand shifts—consisting of mining, textiles and leather, utilities, construction, hotels and restaurants, financial intermediation, real estate activities, education, health and social work, and other services—contributed 0.89 percentage points to aggregate labor productivity growth over the whole sample period (Table 4). Most of those industries experienced an increase in relative size, which translated into an overall contribution of 0.35 percentage points. The industries with the largest relative size effect were mining and other services (0.17 percentage points each). These effects were partly offset by a negative contribution of 0.22 percentage points from real estate activities. Mining and other services experienced an increase in relative output price and in the share of hours worked (Table B.5 in the Appendix).

The decline in the importance of agriculture and some manufacturing (noticeably food, beverage, and tobacco; textiles and leather; basic and fabricated metal; electrical and optical products; and transportation equipment) in terms of the share of hours worked was due to a strong and positive supply shift in these industries, together with an increased competition from emerging economies and other countries. These industries, with their relatively strong improvements in productivity, required relatively less labor to meet demand. In contrast, other business services and other services, which experienced a strong increase in demand, had to employ relatively more labor to meet the increase in demand due to their relatively lower labor productivity growth.

The United States

Over the 1981–2007 sample period, labor productivity in the U.S. business sector increased by 1.6 percent per year (Table 5). It accelerated from 1.3 percent per year during the 1981–95 sub-period to 2.1 percent per year during the 1995–2000 sub-period, and remained at 1.9 percent per year in 2000–07.[24]

In the 1981–2007 period, other business services contributed 0.49 percentage points, followed by financial intermediation (0.25 percentage points) and real estate activities (0.26 percentage points). For other business services, the total contribution was mainly the result of the relative size effect, which originated in substantial increases in the share of hours worked.

Notably, the electrical and optical products manufacturing industry achieved the largest pure productivity effect at 0.40 percentage points per year in 1981–2007. However, the productivity effect was offset by the decline in relative size of the industry due to a substantial decline in its share of hours worked (from 3.0 percent in 1981 to 1.4 percent in 2007) and in its relative output price (its index declined from 2.0 in 1981 to 0.4 in 2007, an 80.0 percent reduction) (Table B.6 in the Appendix). As a result, the total contribution from the industry was –0.01 percentage points. This was true for every sub-period of the sample. It is also worth noting that the pure productivity effect for construction and real estate activities was negative or very small for every sub-period, but it was more than compensated by positive relative size effects from an increase in the share of hours worked and an increase in output price. Consequently, the total contribution from the two industries was positive and significant.

As in Canada, the demand-driven industries were the main force in aggregate labor productivity growth in the United States over the whole sample period. The group contributed 1.54 percentage points, compared to 0.08 percentage points for supply-driven industries. Much of the difference was in 1981–95 when the demand-driven group contributed 1.21 percentage points, while the supply-driven group contributed only 0.08 percentage points. In the next two sub-periods, the contribution from supply-driven industries was 0.46 and 0.57 percentage points, compared to 1.67 and 1.34 percentage points for demand-driven industries, respectively.

Over the whole sample period the pure productivity effect was 1.47 percentage points per year for the supply-driven industries, while for the demand-driven industries, it was only 0.56 percentage points. But, the relative size for demand-driven industries improved significantly relative to supply-driven industries over this period. As a result, the total contribution to aggregate labor productivity was much larger for demand-driven industries (1.54 percentage points) than for supply-driven industries (0.08 percentage points).

In the post-2000 period aggregate labor productivity growth was 1.1 percent per year in Canada, while in the United States it was 1.9 percent per year. The growth gap between the two countries was mainly due to much larger negative contributions from many manufacturing industries and smaller positive contributions from some major services industries (e.g., real estate activities, other business activities, education, and health and social work) (Figure C.8 in the Appendix).

[24]Industry contribution to aggregate labor productivity growth in the United States for the three sub-periods is reported in Tables B.8a, B.8b, and B.8c in the Appendix.

TABLE 5

INDUSTRY CONTRIBUTIONS TO REAL GDP PER HOUR GROWTH IN THE U.S. BUSINESS SECTOR (AVERAGE ANNUAL PERCENTAGE POINTS, 1981–2007)

	Pure Productivity Effect			Relative Size Effect			Interaction				
Industry	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total	Gross Output	Inter. Inputs	Sub Total	Total	Net Shift
Agriculture	0.11	0.04	0.07	–0.17	–0.08	–0.09	–0.01	0.00	–0.01	–0.03	S+
Mining	0.09	0.02	0.07	–0.15	–0.06	–0.08	–0.03	–0.01	–0.02	–0.03	D–
Food, beverage, tobacco	0.13	0.11	0.02	–0.18	–0.15	–0.02	–0.01	0.00	0.00	–0.01	S+
Textiles, leather	0.08	0.04	0.04	–0.16	–0.10	–0.06	–0.01	0.00	–0.01	–0.03	D–
Wood	0.02	0.01	0.01	–0.02	–0.01	–0.01	0.00	0.00	0.00	0.00	S+
Paper, printing	0.07	0.06	0.01	–0.07	–0.06	–0.01	0.00	0.00	0.00	0.00	D+
Coke, petroleum	0.13	0.08	0.05	–0.17	–0.14	–0.03	–0.01	0.00	–0.01	0.01	S+
Chemicals	0.12	0.07	0.05	–0.13	–0.10	–0.02	0.00	0.00	0.00	0.03	S+
Rubber, plastics	0.05	0.03	0.02	–0.03	–0.02	–0.01	0.00	0.00	0.00	0.00	S+
Non-metallic mineral	0.02	0.01	0.01	–0.03	–0.02	–0.01	0.00	0.00	0.00	0.00	S+
Basic & fabricated metal	0.10	0.07	0.03	–0.20	–0.13	–0.07	0.00	0.00	0.00	–0.05	S+
Machinery	0.07	0.06	0.02	–0.14	–0.09	–0.05	0.00	–0.02	0.02	–0.01	S+
Electrical & optical	0.70	0.30	0.40	–0.62	–0.28	–0.35	–0.07	0.00	–0.06	–0.01	S+
Transport equipment	0.26	0.18	0.07	–0.23	–0.16	–0.06	–0.01	0.00	–0.01	0.00	S+
Manufacturing n.e.c.	0.03	0.02	0.01	–0.04	–0.02	–0.01	0.00	0.00	0.00	0.00	S+
Utilities	0.04	–0.01	0.05	–0.09	–0.07	–0.02	–0.01	0.00	0.00	0.03	S+
Construction	–0.04	0.03	–0.07	0.19	0.02	0.16	0.00	0.00	0.00	0.09	D+
Sale & repair of motor vehicles	0.08	0.03	0.05	–0.04	0.00	–0.03	0.00	0.00	0.00	0.01	S+
Wholesale trade	0.29	0.06	0.22	–0.18	–0.02	–0.16	–0.01	0.00	–0.01	0.05	S+
Retail trade	0.31	0.11	0.20	–0.16	–0.01	–0.14	–0.01	0.00	–0.01	0.05	S+
Hotels and restaurants	0.03	0.02	0.00	0.07	0.02	0.05	0.00	0.00	0.00	0.06	D+
Transport and storage	0.09	0.01	0.08	–0.06	0.00	–0.05	0.00	0.00	0.00	0.03	S+
Post and telecommunications	0.23	0.12	0.10	–0.13	–0.05	–0.08	–0.01	0.00	–0.01	0.01	S+
Financial intermediation	0.50	0.29	0.21	0.00	–0.04	0.04	0.00	–0.01	0.01	0.25	D+
Real estate activities	0.25	0.11	0.14	0.14	0.02	0.12	0.00	0.00	–0.01	0.26	D+
Other business service	0.44	0.25	0.19	0.40	0.10	0.30	0.00	0.00	0.00	0.49	D+
Education	0.08	0.08	0.00	0.13	0.01	0.12	0.00	0.00	0.00	0.12	D+
Health and social work	0.04	0.08	–0.05	0.35	0.07	0.28	0.00	0.00	0.00	0.24	D+
Other services	0.13	0.11	0.02	0.10	0.01	0.09	0.00	0.00	0.00	0.11	D+
Supply-driven industries	2.78	1.31	1.47	–2.61	–1.37	–1.24	–0.16	–0.01	–0.15	0.08	S+
Demand-driven industries	1.66	1.10	0.56	1.01	–0.01	1.02	–0.04	0.00	–0.04	1.54	D+
Total	4.44	2.41	2.03	–1.60	–1.38	–0.22	–0.20	0.00	–0.20	1.62	

The poor performance of those industries was partly offset by strong performance in mining, construction, wholesale trade, retail trade, and other services.

4. Conclusions

This paper has estimated industry contribution to economic growth in Canada and the United States by developing an analytical framework that is consistent with real GDP in the chained-Fisher index.[25] In measuring industry contribution, the framework considers not only the quantity of output being produced, but also the value of output being produced relative to other industries. The formulation is in contrast to the traditional thinking that considers only the quantity effect and ignores the price effect. By ignoring the price effect, a traditional method underestimates the contribution of the demand-driven industries and overestimates the contribution of the supply-driven industries to the aggregate measures.

This paper demonstrated that demand-driven industries, particularly financial intermediation, real estate activities, and other business services, were the main contributors to real GDP growth in the business sector in the two countries over the 1981–2007 period. They contributed to real GDP growth not only through real output growth but also through increases in the value of their services. However, although some supply-driven manufacturing and service industries (such as electrical and optical products manufacturing, wholesale trade, retail trade, and post and telecommunications) contributed significantly to real GDP growth through real output growth, these contributions were partly offset by declines in relative output price.

Because of increased relative gross output price and the increased share in hours worked for some industries, the demand-driven industries also contributed significantly to aggregate labor productivity over the sample period. In total, they accounted for more than 64 percent of aggregate labor productivity growth in Canada and 95 percent in the United States. This happened despite the fact that some of those industries experienced lower labor productivity growth than other industries. The performance of many manufacturing industries in Canada, which was mainly driven by supply-shifts, was weaker in the post-2000 period than in the 1995–2000 period. The weak performance was mainly responsible for the aggregate labor productivity growth slowdown over these two periods. The slowdown was, in turn, largely responsible for the labor productivity growth gap between Canada and the United States in the post-2000 period.

[25]It should be noted that the framework is a growth accounting analysis. Like other growth accounting approaches, this analysis cannot deal with causality issues, and only examines industry direct contribution. Research should be extended to examine an industry's contribution to improving welfare through wealth creation and spillover effects on other industries. This is necessary for a better understanding of an industry's overall contribution (direct and indirect) to economic growth. In addition, like other studies using data developed based on the Industry Accounts, the industry contribution estimates based on KLEMS databases may be subject to measurement errors due to the difficult nature in measuring outputs and prices of some industries, especially some services industries (e.g., education) where part of output is measured based on inputs. For a detailed discussion of measurement issues for service industries, see Triplett and Bosworth (2004).

Interestingly, the electrical and optical products manufacturing industry, with strong productivity growth, made only a small contribution to both aggregate output and labor productivity growth in Canada and the United States. This was due to its quantity and productivity effects being largely offset by the decline in its output price effect and in its share of hours worked.[26]

References

Almon, M. and J. Tang, "Industrial Structural Change and the Post-2000 Output and Productivity Growth Slowdown: A Canada–U.S. Comparison," *International Productivity Monitor*, 22, 44–81, 2011.

Basu, S. and J. G. Fernald, "Aggregate Productivity and Aggregate Technology," *European Economic Review*, 46, 963–91, 2002.

Baumol, W. J., "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *American Economic Review*, 57, 415–26, 1967.

Chan, K., W. Gu, and J. Tang, "Industry Mix, Plant Turnover and Productivity Growth: A Case Study of the Electronic and Electrical Product Manufacturing," *Transnational Corporations Review*, 4, 11–37, 2012.

Chevalier, M., "Chain Fisher Volume Index Methodology," Statistics Canada Research Paper, Income and Expenditure Accounts Technical Series, Catalogue No. 13-604-MIE, No. 42, 2003.

de Avillez, R., "Sectoral Contributions to Labour Productivity Growth in Canada: Does the Choice of Decomposition Formula Matter?" *International Productivity Monitor*, 24, 97–117, 2012.

Diewert, W. E., "The Quadratic Approximation Lemma and Decompositions of Superlative Indexes," *Journal of Economic and Social Measurement*, 28, 63–88, 2002.

———, "On the Tang and Wang Decomposition of Labour Productivity Growth into Sectoral Effects," Discussion Paper 08-06, Department of Economics, UBC, 2008.

Domar, E., "On the Measurement of Technological Change," *Economic Journal*, 71, 709–29, 1961.

Dumagan, J. C., "A Generalized Exactly Additive Decomposition of Aggregate Labour Productivity Growth," *Review of Income and Wealth*, 59, 157–68, 2013.

Ho, M., S. Rao, and J. Tang, "Sources of Output Growth in Canadian and U.S. Industries in the Information Age," in D. W. Jorgenson (ed.), *Economic Growth in Canada and the United States in the Information Age*, Industry Canada Research Monograph, 83–165, 2004.

Jorgenson, D. W., *Economic Growth in Canada and the United States in the Information Age*, Industry Canada Research Monograph, 2004.

Jorgenson, D. W. and K. Stiroh, "Raising the Speed Limit: U.S. Economic Growth in the Information Age," *Brookings Papers on Economic Activity*, 1, 125–235, 2000.

Jorgenson, D. W., F. M. Gollop, and B. M. Fraumeni, *Productivity and U.S. Economic Growth*, Harvard University Press, Cambridge, MA, 1987.

Jorgenson, D. W., M. S. Ho, and K. Stiroh, "Growth of U. S. Industries and Investments in Information Technology and Higher Education," *Economic Systems Research*, 15, 279–325, 2003.

Nakamura, E., "Demand Shocks and Real GDP Measurement," Mimeo, Harvard University, 2004.

Stiroh, K. J., "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?" *American Economic Review*, 92, 1559–76, 2002.

Strassner, E. H., G. W. Medeiros, and G. M. Smith, "Annual Industry Accounts: Introducing KLEMS Input Estimates for 1997–2003," *Survey of Current Business* (U.S. Bureau of Economic Analysis), 85, 31–65, 2005.

Tang, J., "Offshoring: A Canadian Story," *Transnational Corporations Review*, 2, 51–58, 2010.

Tang, J. and H. do Livramento, "Offshoring and Productivity: A Micro-Data Analysis," *Review of Income and Wealth*, 56, 111–34, 2010.

Tang, J. and W. Wang, "Sources of Aggregate Labour Productivity Growth in Canada and the Unites States," *Canadian Journal of Economics*, 37, 421–44, 2004.

Tang, J., S. Rao, and M. Li, "Sensitivity of Capital Stock and Multifactor Productivity Estimates to Depreciation Assumptions: A Canada–U.S. Comparison," *International Productivity Monitor*, 20, 22–47, 2010.

Triplett, J. E. and B. P. Bosworth, *Productivity in the U.S. Services Sector: New Sources of Economic Growth*, Brookings Institution Press, Washington DC, 2004.

[26]For a detailed discussion of the productivity dynamics in the manufacturing industry, see Chan *et al*. (2012).

van Ark, B., R. Inklaar, and M. Timmer, "The Canada–U.S. Manufacturing Productivity Gap Revisited: New ICOP Results," Research Memorandum GD-51, Groningen Growth and Development Centre, 2002.

Wang, W., "Foreign Multinational Production in Canadian Manufacturing Sector," *Transnational Corporations Review*, 6, 26–41, 2014.

Whelan, K., "A Guide to U.S. Chain Aggregated NIPA Data," *Review of Income and Wealth*, 48, 217–33, 2002.

Wolff, E., "Has Canada Specialized in the Wrong Manufacturing Industries?" Paper presented at the CSLS Conference on Canada–U.S. Manufacturing Productivity Gap, Ottawa, Canada, January 21–22, 2000.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table B.1: Quantity and Price Effects and Net Shifts

Table B.2: Industry Groupings

Table B.3a: Industry Contributions to Real GDP Growth in the Canadian Business Sector (Average Annual Percentage Points, 1981–1995)

Table B.3b: Industry Contributions to Real GDP Growth in the Canadian Business Sector (Average Annual Percentage Points, 1995–2000)

Table B.3c: Industry Contributions to Real GDP Growth in the Canadian Business Sector (Average Annual Percentage Points, 2000–2007)

Table B.4a: Industry Contributions to Real GDP Growth in the U.S. Business Sector (Average Annual Percentage Points, 1981–1995)

Table B.4b: Industry Contributions to Real GDP Growth in the U.S. Business Sector (Average Annual Percentage Points, 1995–2000)

Table B.4c: Industry Contributions to Real GDP Growth in the U.S. Business Sector (Average Annual Percentage Points, 2000–2007)

Table B.5: Relative Size by Industry in Canada, 1981–2007

Table B.6: Relative Size by Industry in the United States, 1981–2007

Table B.7a: Industry Contributions to Real GDP per hour Growth in the Canadian Business Sector (Average Annual Percentage Points, 1981–1995)

Table B.7b: Industry Contributions to Real GDP per hour Growth in the Canadian Business Sector (Average Annual Percentage Points, 1995–2000)

Table B.7c: Industry Contributions to Real GDP per hour Growth in the Canadian Business Sector (Average Annual Percentage Points, 2000–2007)

Table B.8a: Industry Contributions to Real GDP per hour Growth in the U.S. Business Sector (Average Annual Percentage Points, 1981–1995)

Table B.8b: Industry Contributions to Real GDP per hour Growth in the U.S. Business Sector (Average Annual Percentage Points, 1995–2000)

Table B.8c: Industry Contributions to Real GDP per hour Growth in the U.S. Business Sector (Average Annual Percentage Points, 2000–2007)

Figure C.1: Industry Share of Business Sector Hours Worked in Canada and the United States

Figure C.2: The Impact of the Demand and Supply Shifts on Industry Production

Figure C.3: Distribution of Industries with Net Supply/Demand Shifts in Canada

Figure C.4: Distribution of Industries with Net Supply/Demand Shifts in Canada and the United States

Figure C.5: Total Industry Contribution to Real GDP Growth in Canada

Figure C.6: Total Industry Contribution to Real GDP Growth in Canada and the United States, 2000–2007

Figure C.7: Total Industry Contribution to Aggregate Labour Productivity Growth in Canada

Figure C.8: Total Industry Contribution to Aggregate Labour Productivity Growth in Canada and the United States: 2000–2007