Editor's Overview

THIS 28TH ISSUE OF THE *International Productivity Monitor* features articles on the following topics: the measurement of industry contributions to labour productivity growth; the benefits of closing the Aboriginal education gap; the impact of public policies on bargaining power and the pay/productivity linkage; the relationship between employment and productivity growth; and the contribution of ICT diffusion and investment to labour productivity growth.

Industry contributions to aggregate labour productivity growth are sensitive to the choice of decomposition methodology. In the lead article, **Marshall Reinsdorf** from the International Monetary Fund provides a detailed assessment of three of these methodologies. He points out that the methodologies can lead to very different conclusions regarding which sectors are driving productivity growth. For example, in the Generalized Exactly Additive Decomposition (GEAD) manufacturing makes a negative contribution to aggregate productivity growth in Canada in the 2000-2010 period despite its above average productivity growth because of the falling relative price of manufacturing goods. In contrast, mining and oil and gas extraction makes a positive contribution despite its negative productivity growth because of the rising price of output in the mining and oil and gas sector. The CSLS methodology reaches opposite conclusions. Reinsdorf argues that the GEAD mixes price effects with true productivity gains and consequently its estimates of industry productivity contributions are less economically meaningful than the CSLS methodology.

Reinsdorf subsequently develops the Fisher Exactly Additive Decomposition (FEAD) which allows one to derive additive decompositions using the traditional and CSLS decomposition formulas for chained Fisher productivity series, resulting in more useful economic interpretations of industry contributions to productivity change.

The human capital of Aboriginal Canadians is less developed than that of their non-Aboriginal counterparts. The closing of this education gap would generate important economic benefits both for the Aboriginal community and for the overall Canadian economy. In the second article, **Matthew Calver** from the Centre for the Study of Living Standards develops a simulation model to provide estimates of the effects of closing the gap by 2031 for employment, labour productivity, and GDP.

Calver finds that the closing of the education gap would result in an additional 90 thousand jobs for Aboriginal Canadians by 2031. Equally, more education translates into higher individual productivity and income. He estimates that average Aboriginal employment income would increase by $11,236 (2010 dollars) per worker if the education gap closed. This would raise labour productivity growth 0.03 percentage points from an average annual rate of 1.38 per cent to 1.41 per cent over the 2011-2031 period. The combined effect on employment and labour productivity would raise GDP growth by 0.07 percentage points and produce cumulative gains to Canadian GDP of $261 billion (2010 dollars). These results suggest that investment in Aboriginal education will have a high individual and social payoff.

Economists argue that average wages should rise in tandem with labour productivity. Yet despite the importance of productivity for wages and living standards, the productivity agenda does not appear particularly popular with Canadians. In the third article, **Mathieu Dufour** from City University of New York and **Ellen Russell** from Wilfrid Laurier University argue that this lack of enthusiasm for the P word reflects the failure of the gains from productivity to be widely shared with workers. This disjuncture in the pay/productivity linkage in turn is caused by the declining relative bargaining power of workers, in part due to public policies.

Using an econometric analysis, the authors find evidence that the introduction of NAFTA, and changes in EI system, minimum wages, the unemployment rate, and unionization rates have negatively affected the ability of workers to reap the rewards of productivity gains. They point out that policies intended to boost productivity growth would be more popular, and likely more effective, if they were designed to enable the fruits of productivity growth to be more broadly shared.

It is often argued that there is a trade-off between employment growth and productivity growth, with faster employment growth reducing productivity growth. In the fourth article, **Jianmin Tang** from Industry Canada explores this issue though a comprehensive econometric analysis of the drivers of labour productivity growth in OECD countries. He finds that at the aggregate economy level employment growth can have a negative effect on labour productivity though the channels of increased capital intensity and labour quality. More rapid labour supply and employment growth reduces the price of labour and gives employers less incentive to substitute capital for labour, slowing the pace of capital intensity growth, and hence labour productivity growth. Large increases in labour supply and employment can also reduce the rate of growth in labour quality through negative composition effects.

Tang argues however that this negative correlation between employment growth and labour productivity growth should not be viewed as a trade-off between production efficiency and employment. Labour productivity is a partial measure of production efficiency and is affected by changes in capital intensity and labour quality caused by fluctuations in labour supply and employment. Once these two factors are controlled for, however, he finds that employment growth is not negatively correlated with multifactor productivity, a broader measure of production efficiency.

Investment in information and communications technologies (ICT) has been identified as a key driver of productivity advance. In the fifth article, **Gilbert Cette** from the Banque de France, **Christian Clerc** from Université Aix-Marseille and **Lea Bresson** from the Centre National de la Recherche Scientifique and École des Hautes Études en Sciences Sociales examine the contribution of ICT diffusion to labour productivity growth in the United States, Canada, the Euro Zone and the United Kingdom. A key finding is that the contribution of ICT investment to productivity growth, which increased in the 1994-2004 period, has decreased significantly since 2004. This development reflects the fall-off in the rate of growth in the ICT capital stock in volume terms, caused by the slower pace of ICT price decreases due to the slower pace of technological advancement in semi-conductor chips.

The authors identify an ICT diffusion lag from which Canada, the Eurozone, and the United Kingdom suffer in comparison with the United States. They conclude that, at least for the Eurozone, the lower share of workers with post-secondary education, anticompetitive regulations, and labour and product market rigidities explain the lag. They argue that ambitious structural reforms would allow the Eurozone to benefit more from advances in productivity arising from ICT diffusion.

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Measuring Industry Contributions to Labour Productivity Change: A New Formula in a Chained Fisher Index Framework

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ABSTRACT

Canada and the United States use Fisher indexes in their input-output accounts. Existing methods for decomposing aggregate labour productivity growth into industry contributions in a Fisher index framework either leave some productivity growth unaccounted for or are poorly suited for answering relevant questions about the industry sources of productivity growth. This article derives formulas for analyzing industry contributions to productivity change that add up exactly to the aggregate change in productivity and that have useful economic interpretations. These formulas show that the manufacturing sector made a positive contribution to productivity growth in the Canada in 2000-2010 and in the United States in 1998-2012, whereas the widely used GEAD formula implies that manufacturing made a negative contribution. Methods that can be used to decompose chained Laspeyres measures of productivity growth are also developed. These methods would be applicable in countries other than Canada and the United States.

ALTHOUGH THE EFFECTS ON wages and living standards of productivity growth tend to be broad-based, productivity gains tend to be concentrated in certain industries. An analysis of sector or industry contributions to aggregate productivity growth rates is therefore an important part of understanding an economy's productivity performance.

Productivity is always measured by comparing outputs to inputs, but two approaches are possible for defining inputs. First, labour productivity is generally measured using a simple sum of hours of labour inputs. Second, total factor productivity (TFP, also known as multifactor productivity or MFP) is measured with a quantity index of all inputs used in production. This article will focus on methods for analyzing sources of growth in labour productivity. For an economy that does not have large flows of cross-border investment income or large changes in the labour force participation rate, the standard of living ultimately

1 The author is Senior Economist in the Statistics Department at the International Monetary Fund. This article is a revised version of a paper presented at a session on productivity issues organized by the Centre for the Study of Living Standards (CSLS) at the annual meeting of the Canadian Economics Association, May 30-June 1, 2014, Simon Fraser University, Vancouver, British Columbia. At the time, the author was Chief of the National Accounts Research Group at the US Bureau of Economic Analysis. The author is grateful to Andrew Sharpe, Matthew Calver, Jianmin Tang, Doug May and an anonymous referee for helpful comments. The views expressed are those of the author and should not be attributed to the IMF, its managers or Executive Directors. Email: mreinsdorf@imf.org.

depends on labour productivity.[2] The growth of aggregate total factor productivity (TFP) is a critical determinant of labour productivity growth over the long run so an appendix contains a discussion of an additive decomposition of aggregate TFP growth.

The article is organized as follows. In section one, the challenges in the measurement of the contribution of each sector or industry to overall productivity change are identified as the effect of movement of labour between sectors and as the non-additivity introduced by the Fisher index formula and by chaining.[3] In the second section, the three main formulas in the literature on calculating industry contributions to overall productivity change are presented and their advantages and disadvantages are reviewed. The contrasting behaviour of these formulas is then illustrated with data from Canada. For example, according to the CSLS decomposition formula, the total contributions of mining and construction to Canada's productivity growth are negative and the total contribution of manufacturing is positive, but according to the "Generalized Exactly Additive Decomposition" or GEAD formula, the contributions of mining and construction are positive while the contribution of manufacturing is negative.

To overcome the disadvantages of the existing formulas, section three proposes a new formula for exactly decomposing productivity change in a Fisher framework. It then develops a simplified approximation to this formula that is easy to calculate. In an empirical example using data from the United States, the Fisher decomposition formula identifies manufacturing of computers and other durable goods as making a large positive contribution to US productivity, whereas the GEAD formula implies that they dragged down US productivity growth. Also, the GEAD formula identifies health care and the category that contains fast food restaurants as making positive contributions to US productivity growth, while the Fisher decomposition formula implies their contributions were negative.

Challenges in Decomposing Productivity Growth

The first consideration in designing a formula for calculating contributions of individual industries or sectors to aggregate labour productivity growth is that the contributions are supposed to add up exactly to the change in labour productivity at the aggregate level. The aggregate of interest may be all of GDP, the business sector excluding the real estate industry, or a segment of the business sector, such as private business.

Calculating additive contributions to aggregate productivity growth is not a simple problem because differences in inputs of physical, intangible, and human capital, and also differences in technology, cause industries to vary in their labour productivity levels. Differences in labour

2 Changes in prices of exports and imports also affect living standards, but their effects are usually more transitory than effects of productivity gains.

3 The properties of a measure of real output are affected by the choice of index formula and by whether the long-run indexes have a fixed base or are chained. If a fixed base approach is used for the long-run indexes, quantities from all the years are valued at a set of constant prices from an arbitrary base period, while if an annual chaining approach is used for the long-run indexes, the base period changes every year. In the Laspeyres index formula the initial period is the base period, while in the Paasche index formula the final period is the base period. Thus, in the Laspeyres volume index, the initial period quantities and the final period quantities are both valued at the prices of the initial period, while in the Paasche index, the initial period quantities and final period quantities are both valued at the prices of the final period. The Fisher index is the square root of the product of the Laspeyres index and the Paasche index, that is the geometric mean. The short-term indexes used for the annual links that are chained together may be calculated as Laspeyres, Paasche, or Fisher indexes.

productivity levels across industries mean that movement of labour between industries changes aggregate productivity, a phenomenon known as the "labour reallocation effect".[4]

Assigning a jointly produced effect to individual actors involves a certain amount of arbitrariness, so one option for handling the labour reallocation effect is to leave it out of the decomposition. Yet productivity analysts prefer to have a set of industry contributions that completely account for aggregate productivity growth with no residual. This article will argue that economically meaningful contributions to the reallocation effect can be calculated using one of the procedures that have been proposed to decompose the labour reallocation effect.

Another challenge arises in analyzing productivity change using official data from Canada or the United States. Labour productivity is a ratio whose numerator is an output volume measure that either has been constructed by deflating nominal output by a price index or, equivalently, by multiplying base period nominal output by a quantity index. The statistical agencies of Canada and the United States use chained Fisher indexes for this purpose. These indexes have many desirable properties, but Fisher indexes and chained indexes also have the inconvenient property of yielding output volume measures that are not additive.[5] Non-additivity means that a residual will generally exist between the sum of the real output of every industry (as measured by real value added) and real GDP. In contrast, real value added of every industry can be summed to obtain real GDP with no residual when the volume measures come from a "constant price" framework such as one that relies on direct (i.e. non-chained) Laspeyres or Paasche indexes.

The formulas that work well for calculating additive industry contributions to productivity change in a framework of constant price volume measures cease to be additive when applied in a Fisher or chained index framework. In effect, the discrepancy between the sum of the industry output volumes and the aggregate output volume that arises in a Fisher index or chained index framework will translate into a discrepancy between the sum of the productivity change contributions and the aggregate productivity change.

Main Formulas for Contributions to Labour Productivity Growth

Dumagan (2013) recently examined the characteristics of two widely used formulas for calculating contributions to labour productivity growth, which he terms, "the traditional decomposition" and "generalized exactly additive decomposition" or "GEAD." In addition to discussing these two formulas, de Avillez (2012) considered a modified version of the traditional decomposition that was developed by the Centre for the Study of Living Standards (CSLS) (Sharpe, 2010a and 2010b). This section will review these commonly used formulas, and also a variant of the GEAD introduced by Diewert (2013).

The "Traditional" Decomposition

When a single set of constant prices is used to calculate the output volume measures, the output volumes will be exactly additive. Additivity of the volume measures for industry output makes the problem of deriving an additive decomposition formula for labour pro-

4 Edward Denison identified the movement of labour from low-productivity level agriculture to high-productivity level manufacturing as a source of US labour productivity growth in the first half of the 20th century. Nordhaus (2002) calls the contribution to growth from labour reallocation "the Denison effect."

5 Diewert (1978) showed that a direct Fisher index (i.e. one that has not been chained) is approximately additive. We can therefore expect the residual caused by non-additivity to be small in the year immediately after the base year.

ductivity straightforward. The simplest formula for decomposing aggregate productivity change into industry contributions in a constant price framework has become known as "the traditional decomposition".

Let Z_{it} be the constant price measure of labour productivity in the arbitrary industry i and let Z_t be the corresponding measure of aggregate labour productivity. Also, let $l_{it} = L_{it}/L_t$ be the share of aggregate labour used by industry i, where L_{it} is the total of hours of labour used in industry i and L_t is the total over all industries of L_{it}. Then the l_{it} can be used as weights to express Z_t as an average of the Z_{it}:

$$Z_t = \Sigma_i l_{it} Z_{it} \tag{1}$$

Expressing Z_0 in a similar way and breaking the $l_{it}Z_{it}$ - $l_{i0}Z_{i0}$ into a term for the change in productivity plus a term for the change in labour as a share of aggregate labour yields the traditional decomposition formula:

$$(Z_t - Z_0)/Z_0 = \Sigma_i([Z_{it}l_{it} - l_{i0}Z_{i0}]/Z_0)$$

$$= \Sigma_i[l_{i0}(Z_{it} - Z_{i0}) + Z_{i0}(l_{it} - l_{i0}) + (Z_{it} - Z_{i0})(l_{it} - l_{i0})]/Z_0$$

$$= (\Sigma_i((l_{i0}Z_{i0})/Z_0)((Z_{it}/Z_{i0}) - 1) + [(Z_{i0}/Z_0)(l_{it} - l_{i0}) + ((Z_{it} - Z_{i0})/Z_0)(l_{it} - l_{i0})])$$

$$= \Sigma_i(l_{i0}Z_{i0}/Z_0)g(Z_i) + [(Z_{i0}/Z_0)(l_{it} - l_{i0}) + g(Z_i)(l_{it} - l_{i0})]$$

$$= \Sigma_i \hat{c}_i^D + [(Z_{i0}/Z_0)(l_{it} - l_{i0}) + g(Z_i)(l_{it} - l_{i0})] \tag{2}$$

Here the productivity growth rate of industry i, Z_{it}/Z_{i0}-1, has been denoted by $g(Z_i)$ and the direct contribution of within-industry productivity growth, $(l_{i0}Z_{i0}/Z_0)g(Z_i)$, has been denoted by $\hat{c}_i^D$. (The hat is to distinguish this term from the corresponding term of the GEAD formula discussed below, and the D stands for "direct".) The bracketed terms in equation (2) give contributions from labour reallocation, as is evident from their dependence on the change in each industry's share of employment. The term that depends on the base period level of productivity in each industry i will be called the static reallocation effect, while the term that depends on the growth rate of productivity will be called the dynamic reallocation effect.

The CSLS Decomposition

Assuming that all the Z_{it} are greater than 0, the reallocation effect terms in equation (2) imply that above average employment growth in an industry always contributes to productivity growth in a positive way. Equating fast employment growth to productivity growth in this way does not seem to have a sensible economic interpretation. The labour reallocation effect can, however, be decomposed into economically meaningful contributions by measuring each industry's productivity level as a deviation from the overall mean productivity level. Reinsdorf and Yuskavage (2010) offer a justification for such an approach, and Olley and Pakes (1995:1295) also provide an interpretation for this approach in their discussion of the covariance term of their additive expression for aggregate productivity growth. The modification of the traditional decomposition that uses deviations from means was called "the CSLS decomposition" by de Avillez (2012).

The impact on aggregate productivity of a movement of labour between industries depends on whether the productivity level is higher in the industries where the labour is redeployed than in the industries that it left. The CSLS decomposition uses the overall average level of productivity to account for the comparative productivity level of the industry that is receiving or releasing labour resources. In this decomposition, the reallocation effect component of an industry's contribution to aggregate productivity growth is positive if the industry has a below average productivity level and is releasing labour or if the industry has an above average productivity level and is absorbing labour.[6] As noted by Reinsdorf and Yuskavage (2010), an industry that releases labour can be viewed as placing that labour in a pool where it is available to any industry, and an industry that absorbs labour can be viewed as depleting the pool that is available to any industry. The economy's overall average level of productivity can therefore be treated as its opportunity cost of labour and used as a benchmark for measuring industry contributions to the labour reallocation effect.[7]

The CSLS decomposition has the same formula for the direct effect of within-industry productivity growth as the traditional decomposition, but its reallocation effect term is different. In the CSLS decomposition, the measures of productivity level and growth in the reallocation effect terms of equation (2) are re-expressed as deviations from means. In the static reallocation term, Z_{i0} - Z_0 is substituted for Z_{i0}, and in the dynamic reallocation term, the change in the mean productivity levels is subtracted from Z_{it} - Z_{i0}. These substitutions are possible because $\Sigma_i \, l_{it} - l_{i0} = 0$.

Let $\hat{c}_i^R$ be the reallocation effect term in which productivity levels and growth rates are expressed as deviations from means. Also, let the combined static and dynamic labour reallocation effect be:

$$\Sigma_i \hat{c}_i^R = \Sigma_i[(Z_{i0} - Z_0)/Z_0 + ((Z_{it} - Z_{i0}) - (Z_t - Z_0))/Z_0](l_{it} - l_{i0}) \quad (3)$$

In equation (3) an industry that takes labour from other industries has a positive static contribution to aggregate productivity if its productivity level is above average, and it has a positive dynamic contribution to aggregate productivity if its productivity growth is above average. Conversely, an industry that releases labour to be employed by other industries has a positive static contribution to aggregate productivity if its productivity level is below average, and it has a positive dynamic contribution to aggregate productivity if its productivity growth is below average.

An appealing axiom for a formula for industry contributions to productivity change is that the difference between an industry's contribution and the average contribution for an industry of its relative size should be opposite in sign to the effect on the measure of aggregate productivity change of excluding that industry. In particular, if the contribution for the arbitrary industry i is greater than the benchmark "average" value of $w_{i0}g(Z)$, where w_{i0} is the share of industry i in aggregate nominal output in period 0 and $g(Z)$ is the aggregate productivity growth rate, then excluding that industry from the aggregate should have a downward effect on its growth rate. The CSLS formula has this desirable property.

Suppose that some industry, say industry n, matches the aggregate level of productivity in both time periods, so that $Z_{n0} = Z_0$ and $Z_{nt} = Z_t$. Then excluding this industry will not change aggregate productivity regardless of how its labour input changes. Consistent with this, if $l_{nt} \neq l_{n0}$ the CSLS formula estimate of this

6 The implicit assumption is that an industry's average productivity Z_{i0} is equal to or closely related to the productivity of the marginal labour that it releases or absorbs. An alternative to this assumption would be to assume that the marginal revenue product of labour in an industry is proportional to hourly compensation in that industry.

7 An alternative assumption would be that labour that is released goes into an industry with a productivity level of zero, and labour that is absorbed comes from this industry. This assumption implies the traditional decomposition and the "generalized exactly additive decomposition" (discussed below).

industry's contribution to aggregate productivity change will equal $w_{n0}g(Z)$.

Choice of Prices for the Volume Calculations in the Traditional or CSLS Decompositions

A weakness of the usual specification of both the traditional formula and the CSLS formula is that the selection of the reference period for the constant prices that are used to measure the Z_{i0} and the Z_{it} is left up to the discretion of the researcher. This makes the results depend in an arbitrary way on the researcher's choice of a base period for prices. Indeed, a researcher might even be able to manipulate the results by selecting a particular base period.

The relevant prices for measuring a volume change are those of the two periods between which the volume change is measured, so the reference period for prices should be one of these periods. The Laspeyres quantity index uses the prices of the initial period, while the Paasche quantity index uses the prices of the end period.

The Laspeyres quantity index is more convenient to use than the Paasche index. In the notation of equations (2) and (3), the Laspeyres quantity index takes its prices from period 0, making Z_{i0} equal to nominal output per hour. To calculate a Laspeyres volume measure for the arbitrary industry i, nominal output of industry i in time period t is deflated by a Paasche price index, denoted by P_{it}^{P}. This makes the prices used for the real output measure in Z_{it} also those of period 0.

Denote the contribution of within-industry productivity growth in industry i when period 0 is the base period for prices by c_i^D. Defining the base period for prices in this way allows $l_{i0}Z_{i0}/Z_0$ to be simplified to w_{i0}, so $c_i^D = w_{i0}g(Z_i)$. Substituting w_{i0} for $l_{i0}Z_{i0}/Z_0$ in all the terms of equation (2) yields a convenient expression for calculating the traditional decomposition:

$$
\begin{aligned}
(Z_t - Z_0)/Z_0 &= \Sigma_i w_{i0} g(Z_i) + w_{i0}(l_{it}/l_{i0} - 1) \\
&\quad + w_{i0} g(Z_i)(l_{it}/l_{i0} - 1) \\
&= \Sigma_i c_i^D + w_{i0}(l_{it}/l_{i0} - 1) \\
&\quad + w_{i0} g(Z_i)(l_{it}/l_{i0} - 1) \qquad (4)
\end{aligned}
$$

Making similar substitutions in the reallocation effect terms of equation (3), the reallocation effect part of the CSLS decomposition is:

$$
\begin{aligned}
\hat{c}_i^R &= l_{i0}[(Z_{i0} - Z_0)/Z_0 + Z_{i0}(Z_{it}/Z_{i0} - 1) \\
&\quad - (Z_t - Z_0))/Z_0](l_{it}/l_{i0} - 1) \\
&= [(w_{i0} - l_{i0}) + (w_{i0}(Z_{it}/Z_{i0} - 1) \\
&\quad - l_{i0}(Z_t/Z_0 - 1))]\ (l_{it}/l_{i0} - 1) \\
&= [w_{i0} - l_{i0} + w_{i0} g(Z_i) \\
&\quad - l_{i0} g(Z)](l_{it}/l_{i0} - 1) \qquad (5)
\end{aligned}
$$

The "Generalized Exactly Additive Decomposition"

A residual between the sum of the contributions and aggregate productivity growth will generally exist when a traditional or CSLS formula is applied in a Fisher or chained index framework. To eliminate this troublesome residual, researchers have sought a contributions formula that is exactly additive in all frameworks.

A solution to the problem of the residual was proposed by Tang and Wang (2004). Because the decomposition formula in Tang and Wang (2004) is applicable to superlative quantity index measures, to chained measures, and to Laspeyres volume measures, Dumagan (2013) terms it the "generalized exactly additive decomposition" or GEAD. This decomposition has been widely accepted in the literature and is often used in practice.

The GEAD formula normalizes the prices of individual industries by dividing each individual price by the deflator of the top-level aggregate. Let P_{it} denote the price index for the output (value added) of industry i, let F_t be the aggregate price index at time t, and let $p_{it} = P_{it}/F_t$ be the real price received by industry i at time t. Similarly, in period 0, $p_{i0} = P_{i0}/F_0$. In addition, let labour productivity in industry i be $X_{it} = (Y_{it}/P_{it})/L_{it}$. Then if Y_t is aggregate nominal value added in period t, aggregate labour productivity X_t is defined as $(Y_t/F_t)/L_t$. It can be written as:

$$X_t = \Sigma_i \, p_{it} \, l_{it} \, X_{it} \qquad (6)$$

The change in labour productivity from period 0 to period t is:

$$g(X) \equiv \frac{X_t - X_0}{X_0}$$

$$= \frac{\Sigma_i p_{it} l_{it} X_{it}}{\Sigma_i p_{i0} l_{i0} X_{i0}} - 1 \qquad (7)$$

Now let $w_{i0} = Y_{i0}/Y_0$ and note that $w_{i0} = p_{i0} l_{i0} x_{i0} / \Sigma_j \, p_{j0} l_{j0} x_{j0}$. Then:

$$g(X) = \Sigma_i \, w_{i0} \, [(p_{it}/p_{i0})(l_{it}/l_{i0})(X_{it}/X_{i0}) - 1]$$

$$= \Sigma_i \, w_{i0} \, [(p_{it}/p_{i0})(l_{it}/l_{i0})(1+g(X_i)) - 1]$$

$$= \Sigma_i \, w_{i0} \, [(p_{it}/p_{i0})(l_{it}/l_{i0}) - 1)(1+g(X_i)) + g(X_i)]$$

$$= \Sigma_i \, (w_{i0}/l_{i0})[(p_{it}/p_{i0})l_{it} - l_{i0}](1+g(X_i)) + w_{i0} \, g(X_i) \qquad (8)$$

In the last line of equation (8), the term $(w_{i0}/l_{i0})[(p_{it}/p_{i0})l_{it} - l_{i0})](1+g(X_i))$ represents a reallocation effect c_i^R, which reflects both price growth and employment growth. The final term gives the direct contribution of within-industry labour productivity growth to aggregate productivity growth, $c_i^D = w_{i0} \, g(X_i)$. The formula for c_i^D shows that the GEAD uses the appropriate base period for the prices that underlie the volume measures used to calculate productivity.

The reallocation effect of equation (8) can be broken into a static reallocation effect and a dynamic reallocation effect. Defining x_{i0} as X_{i0}/X_0, the relative productivity of industry i in period 0, the total contribution from reallocation in the GEAD can be written as:

$$c_i^R = (w_{i0}/l_{i0})[(p_{it}/p_{i0})l_{it} - l_{i0}](1+g(X_i))$$

$$= (w_{i0}/p_{i0}l_{i0})(p_{it}l_{it} - p_{i0}l_{i0}) + (w_{i0}/p_{i0}l_{i0})(p_{it}l_{it} - p_{i0}l_{i0})g(X_i)$$

$$= x_{i0}(p_{it}l_{it} - p_{i0}l_{i0}) + x_{i0}(p_{it}l_{it} - p_{i0}l_{i0})g(X_i) \qquad (9)$$

Reallocation of labour towards industry i occurs when $l_{it} > l_{i0}$. Under the assumption that $g(X_i) > -1$, the reallocation contribution will be positive if $p_{it}l_{it}/p_{i0}l_{i0} > 1$. If $p_{it} = p_{i0}$ then c_i^R is positive when the arbitrary industry i is a net recipient of reallocated labour and negative when it releases labour to be reallocated to other industries. Also, a sufficiently large increase in the price of the good that an industry produces (or fall in the prices of the goods that it uses as intermediate inputs) will cause p_{it}/p_{i0} to exceed l_{i0}/l_{it}, making $c_i^R > 0$. In the simple case of $l_{it} = l_{i0}$, c_i^R is positive when the real price that industry i receives for its output rises.

The Three-Component Version of the GEAD

Diewert (2013:5) has extended the approach of Tang and Wang (2004) to distinguish the price changes as a separate factor, in effect breaking apart the $p_{it}l_{it}$ effect of the standard GEAD formula. By treating all elements of the decomposition symmetrically, Diewert is able to express the total contribution of the arbitrary industry i to aggregate productivity growth as the sum of three similar terms. The terms of the three-component GEAD show the contributions of within-industry productivity growth, given the industry's price and labour growth; price growth, given the industry's productivity and labour growth; and labour share growth, given the industry's productivity and price growth, respectively:

$$c_i(\Delta X_i) = w_{i0}g(Xi)[1 + \frac{1}{2}g(p_i) + \frac{1}{2}\ g(l_i) + \frac{1}{3}g(p_i)g(l_i)] \quad (10)$$

$$c_i(\Delta p_i) = w_{i0}g(p_i)[1 + \frac{1}{2}\ g(X_i) + \frac{1}{2}\ g(l_i) + \frac{1}{3}\ g(X_i)g(l_i)] \quad (11)$$

$$c_i(\Delta l_i) = w_{i0}g(l_i)[1 + \frac{1}{2}\ g(X_i) + \frac{1}{2}\ g(p_i) + \frac{1}{3}\ g(X_i)g(p_i)] \quad (12)$$

Why a New Formula is Needed for the Fisher Volume Framework

The three-component version of the GEAD has an appealing symmetry in its treatment of each variable and both versions of the GEAD formula are versatile enough to produce exactly additive contributions regardless of the type of index used to create the output volume measures.

Nevertheless, the versatility of the GEAD comes at the cost of a lack of an appealing economic interpretation for the total contribution of an industry to the economy's productivity growth. The behavior of the total contribution is influenced by the treatment of changes in labour inputs and output prices in the term for the reallocation effect. Because of the treatment of labour input growth and output price growth, discrepancies are possible between the sign of the total contribution of the arbitrary industry *i* to aggregate productivity growth net of the size-adjusted average contribution of $w_{i0}\ g(X)$ and the sign of the change in aggregate productivity growth that would be caused by excluding industry *i* from the aggregate. Normally, excluding a high outlier from the sample results in a lower estimate of the mean, but in the case of the GEAD, excluding an industry whose total contribution is relatively large may paradoxically have a positive effect on aggregate productivity growth.[8]

This sort of paradox can arise because of the treatment of changes in labor inputs and output prices in the reallocation effect term of the GEAD. As in the traditional formula, rapid growth in employment in an industry is treatest as automatically adding to aggregate productivity growth. Yet, even though high employment growth in an industry can be a source of an increase in aggregate output if it means that the industry is providing jobs for people who would otherwise have been unemployed, raising aggregate output should not be confused with raising the average output per hour of those persons who are employed.[9]

Above average growth in an industry's output price has a similar effect on the reallocation effect term of the GEAD to above average growth in labour inputs. For example, suppose there is a disruption in the supply of an import that competes with a product produced by a domestic industry that causes the

8 Suppose that an industry with below average productivity growth has a large total contribution because rapid growth in its output price gives it a positive reallocation effect term. If the boundary of the aggregate whose productivity is being analyzed were redefined to exclude this industry, the new aggregate would have a lower aggregate price index and faster overall productivity growth.

9 To reflect the way the movement of labour into an industry with above average productivity raises overall productivity, the formula for c_i^R could be modified by replacing x_{i0} with x_{i0}-1. This substitution would, however, necessitate some further modification so that the contributions again add up to the correct total: $\Sigma_i\ (p_{it}l_{it} - p_{i0}l_{i0}) + \Sigma_i\ (p_{it}l_{it} - p_{i0}l_{i0})g(X_i)$ may not equal 0.

domestic industry to enjoy a pricing windfall. The pricing windfall may result in the industry being counted as contributing positively to economy-wide productivity growth.

Nevertheless, treating an increase in the price that an industry receives for its output (or a decrease in the prices that it pays for intermediate inputs) as a positive contribution by the industry to aggregate productivity growth is inconsistent with the conceptual definition of productivity growth as an outward movement in the production possibility frontier caused by improvements in technology or in the organization of production.[10]

To avoid ambiguity, non-overlapping definitions of concepts are needed, so the definition of productivity growth must not be expanded so much that it encompasses direct effects of price movements. Prices do, of course, affect the weights in the quantity indexes that are used in the practical definition of productivity growth as the difference between the change in the quantity index for output and the change in the quantity index for inputs. However, these influences on weights are indirect effects, making the index more sensitive to some quantity changes and less sensitive to others. If every good has the same growth rate in its quantity, so that there is no substitution, prices will have no effect on the quantity index.

Including price effects with productivity gains as properly defined may cause true productivity developments to be masked by the price effects.[11] True productivity gains may be a *cause* of low or negative price changes because they result in cost savings that are passed on to buyers. When an industry experiences unusually high or usually low productivity growth, the impacts on real output and prices can be expected to tend to offset each other. The causality that generates an inverse relationship between industry productivity and industry output price can also run from prices to productivity. An exogenous increase in the price that an industry receives for its output may cause it to expand in a way that decreases its measured productivity because it operates under decreasing returns to scale; for example, mining industries tend to open or operate sites with lower grades of ore or more difficult conditions only when prices are high.

The three-component GEAD is more flexible in its treatment of price changes than the original GEAD, so it offers a partial solution for those analysts who want to exclude price changes from the contributions to productivity growth. If the price change term $c_i(\Delta p_i)$ is left out when adding up the total contribution, then only a small residual between the sum of the total contributions and the growth rate of aggregate productivity will be generated. Nevertheless, the property of exact additivity is sacrificed under this approach.

An Illustration using Data for the Canadian Business Sector

To illustrate the differences between the existing decomposition methods, Table 1 presents alternative decompositions of productivity growth of the Canadian business sector between 2000 and 2010 into contributions from two-digit NAICS sectors.[12] For the CSLS decomposition, the base year for prices is defined to match the base year for productivity growth, so the CSLS decomposition

10 In some contexts, a rise in real GDP caused by eliminating allocative inefficiencies might also be called a productivity gain, and in practice it would likely be measured as a productivity gain, but movements along the production possibility frontier to a more efficient allocation are conceptually distinct from outward shifts in the position of the frontier.

11 In the definition of productivity as real output divided by real inputs, prices have an indirect role as weights. Yet direct effects of price changes on revenue or input costs are excluded from the measures of change in real output or real inputs.

Table 1

Alternative Decompositions of Labour Productivity Growth in the Canadian Business Sector, 2000-2010

(simple averages of annual growth rates)

	Effect of Within-Sector Productivity Growth		Total Contributions		Excluding Price Term of Three-Component GEAD	
	CSLS and GEAD (1)	Three-Component GEAD (2)	CSLS (3)	GEAD and Three-Component GEAD (4)	Effect of Change in Real Price (5)	GEAD Total excluding Price Effect (6=4-5)
Business sector industries	0.82	0.65	0.76	0.80	-0.02	0.82
Agriculture, forestry, fishing and hunting	0.11	0.08	0.14	-0.06	-0.05	-0.01
Mining and oil and gas extraction	-0.21	-0.31	-0.06	0.28	0.29	-0.01
Utilities	0.00	0.00	0.01	-0.01	-0.02	0.01
Construction	0.01	0.01	-0.10	0.44	0.17	0.27
Manufacturing	0.23	0.18	0.07	-0.83	-0.33	-0.50
Wholesale trade	0.23	0.21	0.22	0.10	-0.05	0.15
Retail trade	0.17	0.17	0.15	0.14	-0.05	0.19
Transportation and warehousing	0.03	0.03	0.03	0.03	0.00	0.03
Information and cultural industries	0.10	0.10	0.10	0.06	-0.04	0.10
FIRE	0.04	0.05	0.16	0.20	-0.09	0.29
Professional, scientific & technical services	0.06	0.07	0.05	0.18	0.05	0.13
ASWMRS	0.01	0.01	-0.05	0.11	0.03	0.08
Arts, entertainment and recreation	0.00	0.00	-0.01	0.01	0.00	0.01
Accommodation and food services	0.02	0.02	0.03	0.02	0.01	0.01
Other private services	0.04	0.04	0.02	0.12	0.05	0.07

Source: CSLS calculations based on Statistics Canada Canadian Productivity Accounts.

Note: Output is defined as in business sector industries as total output in all two-digit NAICS sectors except for educational services, health care and social assistance, and public administration. Owner-occupied dwellings are excluded.

Note: ASWMRS is administrative and support, waste management and remediation services; FIRE is finance and insurance and real estate and rental and leasing.

gives the same numbers for the contributions of within-industry productivity growth as the standard GEAD formula. [13]

The contributions from within-sector improvements in labour productivity calculated from the CSLS and standard GEAD formulas slightly more than account for the aggregate productivity growth of the business sector of Canada, with of total of 0.82 percentage points (first column of numbers in Table 1). The man-

12 Data from Statistics Canada's Canadian Productivity Accounts were used to calculate these contributions. I am grateful to Andrew Sharpe and Matthew Calver from the Centre for the Study of Living Standards for assistance with these calculations.

13 Note that the CSLS contributions in Table 1 are not rescaled to add up to the aggregate productivity change, a step that is sometimes taken to deal with the non-additivity of the CSLS formula in a Fisher index framework. The discrepancy between the sum of the total contributions calculated with the CSLS formula, which is 0.76 percentage points, and the aggregate productivity growth rate of 0.80 per cent per year shows the size of the non-additivity problem when the CSLS or traditional formula is applied in a Fisher index framework.

ufacturing and wholesale trade sectors have the largest positive contributions from within-sector productivity gains, each 0.23 percentage points, while the mining and oil and gas extraction sector has a sizeable negative contribution, at –0.21 percentage points.

In the three-component GEAD, the contribution of within-sector productivity (equation (10)) includes separate terms for interactions with changes in prices and labour shares that are not included in the standard GEAD. The interactions make the mining sector's contribution more negative and make the manufacturing sector's contribution less positive; these changes in absolute magnitude reflect the fact that output prices were rising in the case of mining and oil and gas and falling in the case of manufacturing. Looking at the economy-wide totals, the three-component GEAD implies that about four-fifths of the business sector's productivity growth comes from within-sector labour productivity growth, about one-fifth comes from labour reallocation, and a small negative amount comes from the contributions of real price changes.

The total contributions of each sector to Canada's labour productivity growth are shown in the middle pair of columns of Table 1. The GEAD method gives a starkly different picture from the CSLS method. For example, according to the CSLS method, the agriculture, forestry and fishing sector made a large positive contribution to Canada's productivity growth, manufacturing made a modest positive contribution, and construction and mining and oil and gas both made negative contributions. According to the GEAD, on the other hand, manufacturing made a very large negative contribution, agriculture and forestry made a small negative contribution, and construction and mining and oil and gas made large positive contributions.

The GEAD contribution for manufacturing reflects the combination of falling real prices and falling employment that this sector was suffering during the 2000-2010 period. On the other hand, the GEAD contribution of the mining and oil and gas sector reflects the real price increases that sector enjoyed. Real price changes are also the main cause of most of the other discrepancies between the CSLS and GEAD contributions. Indeed, the theoretical prediction that the real price change terms would tend to cancel out the within-sector productivity growth terms is confirmed in Table 1: the correlation between the price contributions of the three-component GEAD (next-to-last column) and the within-sector productivity growth contributions (first column of numbers) is –0.81.

The pattern of contributions to productivity growth in Canada from the GEAD closely corresponds to contributions to nominal output growth, as shown in Table 2. Sorting the 2-digit NAICS codes based on contributions to the growth in nominal GDP results in almost the same ordering as sorting them by the contributions to productivity growth measured by the GEAD. The GEAD formula gives an exactly additive decomposition regardless of how the aggregate deflator in the formula is specified. It can therefore be used to decompose the change in nominal output per hour by letting the aggregate deflator equal 1, but the ordering of the GEAD contributions is not very sensitive to the choice of the aggregate deflator.

Exactly Additive Contributions to Productivity Growth in a Fisher Framework

The Fisher index is defined as an unweighted geometric mean of Laspeyres and Paasche indexes, but it can also be expressed as a weighted arithmetic average of these two indexes. The weights needed to express the aggregate Fisher index as an arithmetic average also provide an exactly additive decomposition. As this decomposition is not general like the GEAD, it can be termed the "Fisher exactly additive decomposition," or FEAD.

Let Q_t^L, Q_t^P and Q_t^F be the aggregate Laspeyres, Paasche and Fisher quantity indexes, respec-

Table 2

Contributions to Nominal Business Sector Output Growth and GEAD Contributions to Business Sector Labour Productivity in Canada at the Two-Digit NAICS Level, 2000-2010

(GDP at basic prices)

Sector	Nominal GDP, 2000, billions	Nominal GDP, 2010, billions	Contribution to Nominal Business Sector Output Growth (PCP)	GEAD Contribution to Annual Productivity Growth (PCP)	Relative Contribution to Nominal Output Growth	Relative Contribution to Productivity Growth
Business sector industries	777.0	1150.0	48.0	0.80	100.0	100.0
Construction	47.7	113.3	8.4	0.44	17.6	55.0
FIRE	116.5	181.8	8.4	0.20	17.5	25.0
Mining and oil and gas extraction	61.1	114.7	6.9	0.28	14.4	35.0
Professional, scientific & technical services	48.7	86.1	4.8	0.18	10.0	22.5
Retail trade	49.2	82.6	4.3	0.14	8.9	17.5
Wholesale trade	51.8	82.0	3.9	0.10	8.1	12.5
Other private services	38.7	65.8	3.5	0.12	7.3	15.0
ASWMRS	22.5	42.9	2.6	0.11	5.5	13.8
Transportation and warehousing	43.7	63.1	2.5	0.03	5.2	3.8
Information and cultural industries	31.4	49.4	2.3	0.06	4.8	7.5
Accommodation and food services	22.2	32.2	1.3	0.02	2.7	2.5
Utilities	26.3	35.3	1.2	-0.01	2.4	-1.3
Arts, entertainment and recreation	7.1	11.0	0.5	0.01	1.0	1.3
Agriculture, forestry, fishing and hunting	21.2	23.0	0.2	-0.06	0.5	-7.5
Manufacturing	188.9	166.9	-2.8	-0.83	-5.9	-103.8

Source: CSLS calculations based on Statistics Canada Canadian Productivity Accounts.

Note: Output is defined as in business sector industries as total output in all two-digit NAICS sectors except for educational services, health care and social assistance, and public administration. Owner-occupied dwellings are excluded.

Note: ASWMRS is administrative and support, waste management and remediation services; FIRE is finance and insurance and real estate and rental and leasing.

Note: PCP is short for percentage points

tively and let λ be proportional to the square root of the Paasche index. Two equivalent expressions for λ are $\lambda = (Q_t^P)^{0.5} / [(Q_t^P)^{0.5} + (Q_t^L)^{0.5}]$, and $\lambda = (P_t^P)^{0.5} / [(P_t^P)^{0.5} + (P_t^L)^{0.5}]$, where P_t^P and P_t^L are the Paasche and Laspeyres price indexes. Then:

$$Q_t^F = \frac{Q_t^L[Q_t^P]^{0.5} + Q_t^P[Q_t^L]^{0.5}}{[Q_t^P]^{0.5} + [Q_t^L]^{0.5}}$$

$$= \lambda Q_t^L + (1-\lambda)Q_t^P \qquad (13)$$

Assume, as is often the case, that the Laspeyres index is higher than the Paasche index. This implies that the weight on the Laspeyres index, denoted by λ in equation (13), is less than 0.5. For example, assuming that the indexes are not far from 100, a Laspeyres-Paasche spread of 2 percentage points would imply a λ of about 0.4975 because λ approximately equals 0.5 minus one-eighth of this spread.

A linear combination of additive contributions will itself be additive. The traditional decomposition and the CSLS decomposition are both exactly additive when Laspeyres quantity indexes are used to measure real output and also when Paasche quantity indexes are used. Therefore, an additive decomposition of the Fisher measure of productivity change can be derived as a linear combination of a decomposition of the Laspeyres measure of aggregate productivity change and a decomposition of the Paasche measure of aggregate productivity change. The weight on the Laspeyres decomposition is λ and the weight on the Paasche decomposition is $1-\lambda$.

The formulas for the CSLS decomposition in a Laspeyres volume framework are given by equations (4) and (5). As noted, the numerator of Z_{it} in that framework can be calculated by deflating nominal output in period t by Paasche price indexes, P^P_{it}.

To calculate the Paasche volume measure for the arbitrary industry i, the industry's nominal output in period 0 is multiplied by its Laspeyres price index P^L_{it}. To be able to combine the Paasche contributions with the Laspeyres ones, the Paasche productivity measures of period 0 need to have the same weighted average as the Laspeyres ones. This is accomplished by dividing all the volume measures of period 0 and period t (or all the productivity measures) by the aggregate Laspeyres price index, P^L_t. Let V_{i0} be the nominal output of industry i in time 0 and let the Paasche volume measures of productivity in industry i be denoted by z_{i0} and z_{it}. Then:

$$z_{i0} = V_{i0}\,(P^L_{it}/P^L_t)/L_{i0} \tag{14}$$

and

$$z_{it} = V_{it}\,(1/P^L_t)/L_{i0}. \tag{15}$$

The z_{i0} have a weighted average of Z_0 (aggregate labour productivity measured at the prices of period 0) by construction:

$$Z_0 = \Sigma_i\, l_{i0}z_{i0}. \tag{16}$$

The aggregate Paasche productivity measure for period t, denoted by z_t, is:

$$\begin{aligned} z_t &= (\Sigma_i V_{it})(1/P^L_t)/L_t \\ &= \Sigma_i\, l_{it}z_{it} \end{aligned} \tag{17}$$

Equation (14) implies that $l_{i0}z_{i0}/Z_0 = w_{i0}P^L_{it}/P^L_t$. Substituting $l_{i0}P^L_{it}/P^L_t$ for $l_{i0}z_{i0}/Z_0$ and writing the industry and aggregate Paasche output growth rates as $g(z_i)$ and $g(z)$, respectively, gives a convenient decomposition of the Paasche measure of productivity growth:

$$\begin{aligned} (z_t - Z_0)/Z_0 &= \Sigma_i\,[l_{i0}(z_{it} - z_{i0}) + z_{i0}(l_{it} - l_{i0}) \\ &\quad + (z_{it} - z_{i0})(l_{it} - l_{i0})]/Z_0 \\ &= \Sigma_i\,[(l_{i0}z_{i0}/Z_0)(z_{it}/z_{i0} - 1) + (z_{i0}/Z_0) \\ &\quad (l_{it} - l_{i0}) + ((z_{it} - z_{i0})/Z_0)(l_{it} - l_{i0})] \\ &= \Sigma_i\, w_{i0}(P^L_{it}/P^L_t)g(z_i) + [(z_{i0} - Z_0)/Z_0 \\ &\quad + ((z_{it} - z_{i0})-(z_t - Z_0))/Z_0](l_{it} - l_{i0}) \\ &= \Sigma_i\, w_{i0}(P^L_{it}/P^L_t)g(z_i) + [w_{i0}P^L_{it}/P^L_t - l_{i0} \\ &\quad + w_{i0}(P^L_{it}/P^L_t)g(z_i) \\ &\quad - l_{i0}g(z)](l_{it}/l_{i0} - 1) \end{aligned} \tag{18}$$

Combining the Laspeyres productivity term for the contribution from the within-industry productivity growth in equation (4) with its Paasche counterpart in equation (18) gives the contribution of within-industry productivity growth in industry *i* to Fisher aggregate productivity growth:

$$\tilde{c}^D_i = w_{i0}\,[\lambda\, g(Z_i) + (1-\lambda)(P^L_{it}/P^L_t)g(z_i)] \tag{19}$$

Also, the contribution of the reallocation effect to the Fisher measure of productivity change is:

$$\begin{aligned} \tilde{c}^R_i &= (l_{it}/l_{i0} - 1)\{w_{i0}[\lambda\, g(Z_i) + \\ &\quad (1-\lambda)(P^L_{it}/P^L_t)g(z_i)] \\ &\quad - l_{i0} + \lambda\,[w_{i0}g(Z_i) - l_{i0}g(Z)] \\ &\quad + (1-\lambda)[w_{i0}(P^L_{it}/P^L_t)g(z_i) \\ &\quad - l_{i0}g(z)]\} \end{aligned} \tag{20}$$

A Symmetrically Weighted Reallocation Effect

Following Nordhaus (2002), an economic interpretation as a measure of the Baumol effect is often assigned to the dynamic reallocation term of the contribution formulas discussed thus far.[14] Yet the dividing line between the contributions from the dynamic reallocation and within-industry productivity growth is arbitrary within a range. For any γ in the closed interval [0,1]:

$$\frac{l_{it}Z_{it} - l_{i0}Z_{i0}}{Z_0} = [(1-\gamma)l_{i0} + \gamma l_{it}]\frac{Z_{it} - Z_{i0}}{Z_0} + \frac{(1-\gamma)Z_{it} + \gamma Z_{i0}}{Z_0}(l_{it} - l_{i0}) \quad (21)$$

If $l_{it} > l_{i0}$ and $Z_{it} > Z_{i0}$, making γ larger has the effect of shifting weight to the within-industry productivity growth effect and away from the overall reallocation effect.

The traditional, CSLS and standard GEAD formulas implicitly choose a value of 0 for γ, so the dynamic reallocation term must be such that the total of the static and dynamic reallocations terms is $(Z_{it}/Z_0)(l_{it} - l_{i0})$. The implicit assumption in this approach is that the within-industry productivity growth happens before the labour reallocation process begins. A more reasonable assumption is, however, that the processes of within-industry productivity growth and labour reallocation occur simultaneously. That assumption implies a choice of 0.5 for γ. Diewert (2013), for example, achieves symmetry across the terms of his three-component GEAD by letting γ equal 0.5.

Another alternative for choosing a value for γ would be to require that a generalized change in productivity that affects all industries has no effect on the way that the reallocation effect is distributed over industries. In other words, if there is a common factor that affects every industry's productivity by the same amount and also a set of industry-specific factors, the contributions to the reallocation effect should depend only on the industry-specific factors. This invariance property can be achieved by setting γ equal to:

$$\gamma = \frac{Z_t/Z_0}{1 + Z_t/Z_0} \quad (22)$$

We can expect that most of the time aggregate productivity growth will not be great enough to make z_t/z_0 much greater than 1, so this approach to defining γ will lead to a number near 0.5.

If it is assumed that γ is equal to 0.5, $\bar{l}_i \equiv (l_{it} + l_{i0})/2$ and $\bar{Z}_i \equiv (Z_{it} + Z_{i0})/2$, then:

$$(Z_t - Z_0)/Z_0 = \Sigma_i [l_{it}Z_{it} - l_{i0}Z_{i0}]/Z_0$$

$$= \Sigma_i [\bar{l}_i Z_{i0}[(Z_{it} - Z_{i0})/Z_{i0}] + \bar{Z}_i(l_{it} - l_{i0})]/Z_0$$

$$= \Sigma_i 0.5[w_{i0}(1 + l_{it}/l_{i0})g(Z_i) + ((Z_{it}/Z_0) + Z_{i0}/Z_0)(l_{it} - l_{i0})] \quad (23)$$

The contribution of within-industry productivity growth for industry *i* in equation (23) is:

$$\hat{c}_i^{D*} = 0.5w_{i0}(1 + l_{it}/l_{i0})g(Z_i) \quad (24)$$

The reallocation term in equation (23) can be written using deviations from means. This gives the symmetrically weighted version of the CSLS reallocation effect:

$$\hat{c}_i^{R*} = (l_{it} - l_{i0})0.5[(Z_{it} - Z_t)/Z_0 + (Z_{i0} - Z_0)/Z_0]$$

$$= (l_{it}/l_{i0} - 1)0.5[w_{i0}(1 + Z_{it}/Z_{i0}) - l_{i0}(1 + Z_t/Z_0)] \quad (25)$$

The formulas in equations (24) and (25) are from the Laspeyres volume framework, and

14 Baumol hypothesized that over time an increasing share of expenditures would go to products with stagnant productivity. As a result, in the long run, aggregate productivity growth would experience a slowdown. This effect came to be known as "Baumol's disease."

they have counterparts from the Paasche volume framework. The contributions to the productivity change measured using Paasche volumes are:

$$(z_t - Z_0)/Z_0 = \Sigma_i [\,\bar{l}_i z_{i0}[(z_{it} - z_{i0})/z_{i0}]+ \bar{z}_i - 0.5(z_t + Z_0)](l_{it} - l_{i0})]/Z_0$$

$$= \Sigma_i\, 0.5[w_{i0}(P^L_{it}/P^L_t)(1+l_{it}/l_{i0})g(z_i) + (l_{it} - l_{i0})[z_{it} + z_{i0} - (z_t + Z_0)]/Z_0$$

$$= \Sigma_i\, 0.5[w_{i0}(P^L_{it}/P^L_t)(1+l_{it}/l_{i0})g(z_i) + (l_{it}/l_{i0} - 1)w_{i0}(P^L_{it}/P^L_t)[(1+z_{it}/z_{i0}) - l_{i0}(1+z_t/Z_0)] \qquad (26)$$

Combining the Laspeyres and Paasche contribution formulas gives the symmetrically weighted Fisher contribution to the growth formula. The direct contribution to aggregate Fisher productivity growth of industry i's productivity growth is:

$$\grave{c}^D_i = w_{i0}[0.5(1+ l_{it}/l_{i0})][\lambda\, g(Z_i) + (1-\lambda)(P^L_{it}/P^L_t)g(z_i)] \qquad (27)$$

The corresponding Fisher reallocation effect is:

$$\grave{c}^R_i = (l_{it}/l_{i0}-1)0.5[\lambda\,[w_{i0}(1+ Z_{it}/Z_{i0}) - l_{i0}(1+ Z_t/Z_0)] + (1-\lambda)[w_{i0}(P^L_{it}/P^L_t)(1+z_{it}/z_{i0}) - l_{i0}(1+z_t/Z_0)] \qquad (28)$$

Simplified Formula for Fisher Contributions

The Fisher contribution formula can be simplified with only a tiny loss of accuracy by assuming that at the level of detailed industries, the Laspeyres and Paasche indexes are identical. This simplification allows contributions to be calculated from the published data on Fisher indexes: the annual Laspeyres and Paasche indexes needed for the exact formula are not published by the statistical agencies. In the case of the within-industry productivity growth term, the simplified Fisher contribution formula turns out to resemble the three-component GEAD formula.

The first step in calculating simplified Fisher contributions is to determine a value for λ as a function of Laspeyres and Paasche indexes for the economy as a whole. The Laspeyres quantity index for the whole economy can be approximated as an arithmetic average of the quantity indexes for the individual industries in which the weight for any industry i is w_{i0}, industry i's share of aggregate nominal output in the base period. Similarly, the top-level Paasche index is approximated as the weighted harmonic mean of the quantity indexes for the individual industries, where the weight for any industry i is w_{it}.[15] Using these top-level Laspeyres and Paasche indexes, $\lambda = (Q^P_t)^{0.5}/[(Q^P_t)^{0.5} + (Q^L_t)^{0.5}]$.

The assumption that the Laspeyres and Paasche indexes are identical at the level of a detailed industry also implies that $g(Z_i) = g(z_i)=g(X_i)$, where $g(X_i)$ is the Fisher measure of productivity growth. Substituting $g(X_i)$ for $g(z_i)$ and $g(Z_i)$ in equation (27) implies that the within-industry productivity growth term equals $w_{i0}[0.5(1+l_{it}/l_{i0})][\lambda+(1-\lambda)(P^L_{it}/P^L_t)]\, g(X_i)$. But the assumption is that at the industry level the Laspeyres index equals the Fisher index, so we can drop the L superscript on P^L_{it} and write the simplified Fisher contribution of within-industry productivity growth in industry i as:

$$\dot{c}^D_i = w_{i0}[\lambda+(1-\lambda)(P_{it}/P^L_t)][0.5(1+ l_{it}/l_{i0})]\, g(X_i) \approx \grave{c}^D_i \qquad (29)$$

In equation (10), $g(p_i)$ is the growth rate of the price index of industry i relative to the

15 A harmonic mean is calculated by taking reciprocals, averaging, and then taking the reciprocal of the result.

aggregate Fisher price index, so if we approximate the aggregate Laspeyres price index P_t^L by the Fisher index, then $P_{it}/P_t^L \approx 1 + g(p_i)$. Making this substitution, equation (29) becomes:

$$\begin{aligned} \dot{c}_i^D &\approx w_{i0}\,[1 + (1\text{-}\lambda)g(p_i)][1 + 0.5g(l_i)]g(X_i) \\ &= w_{i0}g(X_i)[1 + 0.5g(l_i) + (1\text{-}\lambda)g(p_i) + \\ &\quad 0.5(1\text{-}\lambda)g(p_i)] \\ &\approx w_{i0}\,g(X_i)[1 + 0.5g(l_i) + 0.5g(p_i) + \\ &\quad 0.25g(p_i)g(l_i)] \end{aligned} \qquad (29')$$

The contribution of within-industry productivity growth in the simplified Fisher decomposition has a notable resemblance to the within-industry productivity growth in the three-component GEAD, $c_i(\Delta X_i)$ of equation (10). On the other hand, the term for the labour reallocation effect in the simplified Fisher decomposition is quite different from the one in the three-component GEAD (equation (12)). The simplified reallocation effect is:

$$\begin{aligned} \dot{c}_i^R &= 0.5\{w_{i0}[\lambda + (1\text{-}\lambda)(P_{it}/P_t^L)](1+X_{it}/X_{i0}) \text{ -} \\ &\quad l_{i0}(1+X_t/X_0)]\}(l_{it}/l_{i0} \text{ -}1) \approx \grave{c}_i^R \end{aligned} \qquad (30)$$

This reallocation effect can be written in the notation of equation (12) as:

$$\begin{aligned} \grave{c}_i^R &= g(l_i)\{w_{i0}[1+(1\text{-}\lambda)g(p_i))(1+0.5g(X_i)] \text{ -} \\ &\quad l_{i0}(1+0.5g(X))\} \end{aligned}$$

$$\begin{aligned} &= g(l_i)\{w_{i0}[1+(1\text{-}\lambda)g(p_i)+0.5g(X_i) + 0.5(1\text{-}\lambda) \\ &\quad g(p_i)g(X_i)] \text{ -} l_{i0}(1+0.5g(X))\} \end{aligned} \qquad (30')$$

Chained Fisher Volume Measures of Productivity Change

In addition to bilateral Fisher measures of productivity change that compare two years directly, the GEAD is flexible enough to be applied to chained measures of productivity change. This applicability to chained indexes is a very convenient property. Nevertheless, an algorithm for calculating additive decompositions of a chained productivity measure based on a decomposition formula that is additive in a bilateral context can easily be derived.

The notation for expressing the formula for contributions to a chained measure of productivity growth requires a time subscript t on the contribution to the change from year t−1 to year t. Also we now let Q_t^F denote the direct Fisher quantity index from year t−1 to year t and let X_t denote the index of aggregate labour productivity from year t−1 to year t. The change in aggregate productivity from year t−1 to year t is, then:

$$\begin{aligned} [Q_t^F V_{t-1}/L_t]/[V_{t-1}/L_{t-1}] - 1 &= Q_t^F/(L_t/L_{t-1}) - 1 \\ &= X_t \text{ - } 1 \\ &= \Sigma_i \; \grave{c}_{it}^D + \grave{c}_{it}^R \end{aligned} \qquad (31)$$

The chained Fisher measure of aggregate productivity change from year t−1 to year t+1, equal to $X_t X_{t+1}$, then has a change of:

$$\begin{aligned} Q_{t+1}^F\, Q_t^F/(L_{t+1}/L_{t-1}) - 1 &= [Q_t^F/(L_t/L_{t-1}) - 1] + \\ &\quad [Q_t^F/(L_t/L_{t-1})][\,Q_{t+1}^F\;/(L_{t+1}/L_t) - 1] \\ &= X_t - 1 + X_t(X_{t+1} - 1) \\ &= \Sigma_i \; \grave{c}_{it}^D + \grave{c}_{it}^R + X_t\,(\grave{c}_{i,\,t+1}^D + \grave{c}_{i,\,t+1}^R) \end{aligned} \qquad (32)$$

To add another link to the chain, we can calculate the contributions to the cumulative change in aggregate productivity as:

$$\begin{aligned} X_t - 1 + X_t(X_{t+1} - 1) + X_tX_{t+1}(X_{t+2} - 1) \\ = \Sigma_i \; \grave{c}_{it}^D + \grave{c}_{it}^R + X_t(\grave{c}_{i,\,t+1}^D + \grave{c}_{i,\,t+1}^R) \\ + X_tX_{t+1}(\grave{c}_{i,\,t+2}^D + \grave{c}_{i,\,t+2}^R) \end{aligned} \qquad (33)$$

Table 3

Exact and Approximate Estimates of Aggregate Growth of Labour Productivity in the United States, 1998-2012

(based on total economy output per full-time equivalent worker, per cent per year)

	1999	2000	2001	2002	2003	2004	2005
Using rounded exact contributions	2.51	1.81	0.69	2.79	2.96	2.54	1.38
Using approximation for exact contributions	2.48	1.73	0.61	2.80	2.96	2.49	1.40
Memo: Sum of GEAD contributions	2.48	1.74	0.63	2.79	2.98	2.46	1.40
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Using rounded exact contributions	0.85	0.32	-0.13	2.56	3.34	0.31	0.56
Using approximation for exact contributions	0.86	0.32	-0.12	2.52	3.39	0.31	0.59
Memo: Sum of GEAD contributions	0.85	0.33	-0.15	2.55	3.42	0.28	0.61

Source: Author's calculations based on BEA data.

Additive contributions to chained volume measures can then be calculated by rescaling the contributions to year-over-year productivity change so that they have a common base in the initial time period, and then subsequently summing over time.

Illustration using Data from the US Industry Accounts

To provide empirical evidence on the accuracy of the approximation offered by the simplified Fisher decomposition formulas of equations (27) and (28), the Annual Industry Accounts (AIAs) of the US Bureau of Economic Analysis were used to calculate simplified Fisher contributions shown in Table 3. Aggregate productivity was measured as the ratio of the production approach measure of real GDP from the AIAs to aggregate full-time equivalent employment (FTE).[16] The data covered the years 1998-2012.

In Table 3 the sum of the simplified contributions in each year is shown underneath the aggregate measure of productivity change. The residuals from subtracting the sum of the contributions from the aggregate change are small, implying that the simplified Fisher contribution formula is extremely close to being additive. The average of the residuals is 0.01 percentage points, the square root of the mean of the squared residuals is 0.038 percentage points, and most years have a residual under 0.05 percentage points in magnitude. These residuals may even understate the accuracy of the simplified Fisher formula because rounding errors in the data used for the calculations may contribute to the residuals.

To illustrate the calculation of chained measures of productivity change as described earlier, annual contributions to change for 1998-1999 up to 2011-2012 from both the simplified Fisher contribution formula and the GEAD were chained. The resulting cumulative measures of productivity change in percentage points over a 14-year interval are shown in Table 4. The real estate industry is included even though labour productivity is not a meaningful statistic for that industry because the purpose of the table is to test the performance of contributions formulas under diverse conditions. The calculated contribution of the real estate industry to labour productivity growth is large even though this

16 The production approach measure of real GDP growth is calculated by summing the exactly additive contributions to real GDP growth published in the AIAs. Labour inputs are measured using FTEs rather than hours because the labour data in the AIAs are for FTEs.

Table 4

Industry Contributions to Labour Productivity Growth in the United States Based on FEAD and GEAD Decompositions, 1998-2012

(percentage points)

Sector or Industry	Total Contribution		Within-Sector Productivity Change Contribution			Reallocation Effect Contribution		
	FEAD[b]	GEAD	FEAD[b]	CSLS-Fisher[a]	GEAD	FEAD[b]	CSLS-Fisher[a]	GEAD
Total economy	24.71	24.74	26.45	26.82	28.42	-1.75	-2.11	-3.69
Farms, forestry, fishing	0.48	0.44	0.54	0.56	0.62	-0.06	-0.07	-0.18
Oil and gas extraction	0.68	1.64	0.05	0.04	0.40	0.63	0.64	1.23
Other mining	0.26	0.77	0.19	0.19	0.19	0.06	0.07	0.58
Utilities	0.28	0.31	0.48	0.49	0.55	-0.20	-0.21	-0.24
Construction	-0.63	0.28	-0.81	-0.78	-0.75	0.18	0.15	1.02
Durable goods manufacturing excluding computers	3.13	-1.03	2.83	2.82	2.99	0.30	0.31	-4.01
Computer and electronic products	3.97	-0.18	4.30	4.40	4.74	-0.33	-0.43	-4.91
Nondurable Manufacturing	2.00	1.03	1.93	1.97	2.04	0.07	0.03	-1.01
Wholesale & retail trade	2.58	1.30	2.58	2.57	2.64	0.01	0.01	-1.34
Transportation and warehousing	0.47	0.56	0.55	0.56	0.64	-0.08	-0.10	-0.07
Publishing and motion picture and sound recording	1.11	0.61	1.27	1.29	1.29	-0.16	-0.18	-0.69
Broadcasting, data processing, telecomm. and internet	2.78	0.57	3.37	3.46	3.53	-0.59	-0.68	-2.96
Finance	2.72	1.24	2.61	2.62	2.83	0.11	0.11	-1.58
Real estate, rental and leasing	4.35	4.17	3.86	3.88	3.90	0.50	0.48	0.27
Professional, scientific, and technical services	1.26	3.55	1.03	1.04	1.07	0.22	0.22	2.48
ASWMRS	1.00	1.21	1.08	1.10	1.10	-0.08	-0.10	0.11
Educational services	-0.43	0.58	-0.03	-0.03	-0.03	-0.40	-0.40	0.61
Health care and social assistance	-0.96	3.04	0.24	0.24	0.25	-1.21	-1.21	2.80
Arts, entertainment, recreation, accommodation, food services	-0.62	1.04	0.17	0.19	0.20	-0.79	-0.81	0.85
Other services, except government	-0.57	-0.03	-0.60	-0.60	-0.59	0.03	0.03	0.56
Government	0.85	3.64	0.81	0.82	0.83	0.04	0.03	2.81

a. The CSLS-Fisher has static and dynamic reallocation effect terms, as in equation (20).

b. FEAD indicates a symmetric Fisher Exactly Additive Decomposition calculated as in equations (27) and (28).

Source: Table 3.

industry employs very little labour because the weights in the main part of the contribution formula are based on industry output, not labour inputs.

In the case of the GEAD, price changes and employment changes often influence the contribution estimates in ways that generate counter-intuitive results. In Table 4 the GEAD formula gives large negative reallocation effects for manufacturing, particularly computer manufacturing, and also for the high tech services industries of broadcasting, data processing, telecommunications and internet. Even the total contribution to US productivity growth is negative in the cases of computers and other durable goods manufacturing, which is in sharp contrast to the key role as a driver of US productivity growth that is usually assigned to these industries. In the cases of health care and oil and gas extraction, large output price increases lead to notable positive contributions to US productivity growth in the GEAD framework. Furthermore, the rapid growth of "McJobs", which replaced many of the lost jobs in US manufacturing, helped to give the sector that contains food services a significant positive contribution to US productivity growth based on the GEAD.

The simplified Fisher decomposition formula paints a very different picture from the GEAD of the sources of productivity growth. In particular, the simplified Fisher formula identifies durable goods manufacturing, computer manufacturing and high tech services as important positive drivers of US labour productivity growth. It also implies that food services and health care made negative contributions to aggregate productivity growth.

Finally, the estimates of the reallocation effect using the symmetrically weighted Fisher formula (γ=0.5) and using a formula similar to that of the CSLS for the reallocation effect (γ=0) are shown in the first two columns in the reallocation effect panel of Table 4. The two sets of estimates of contributions from labour reallocation are not very different. The negative reallocation effects are, however, a bit closer to zero using the symmetrically weighted Fisher decomposition, and for the industries with positive contributions of within-sector productivity growth, these positive contribution also tend to be closer to zero. As a result, both the reallocation effect terms and the within-industry productivity growth terms sum up to numbers that are smaller in magnitude when the symmetrically weighted formula is used.

Conclusion

The GEAD formula is widely used to decompose chained Fisher measures of productivity change because it has the advantages of yielding contributions that sum exactly to the change in aggregate productivity and it is relatively straightforward to calculate. However, the GEAD includes the direct effects of output price increases (relative to the GDP deflator) in an industry's total contribution to aggregate productivity growth, and it treats above-average increases in labour inputs as always having a positive impact on aggregate productivity. It thus tends to yield total contributions to productivity growth that resemble contributions to the growth of a rescaled version of nominal GDP per hour worked. Calculations using data from the Canada and the United States provide examples of how this type of contribution can portray the roles of industries with rapidly changing prices or labour inputs in driving aggregate productivity growth in anomalous ways.

The article also develops new decomposition formulas for measures of labour productivity based on direct Fisher and chained Fisher indexes. The simplified Fisher formula is easy to implement using the published data and produces estimates of sector and industry contributions to aggregate productive growth with useful economic interpretations. Under this approach, an industry's total contribution to aggregate productivity growth will also have the appealing property that the deviation from the average contribution (adjusted for the size of the industry) is consistent in sign with the effect that excluding that industry from the group of industries for which aggregate productivity growth is calculated would have on the measure of aggregate productivity growth.

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Appendix 1

Industry Contributions to Total Factor Productivity in a Growth Accounting Framework

Under certain assumptions, aggregate TFP growth can be expressed as a weighted sum of sector contributions using the weights that were introduced by Domar (1961). This result is noteworthy because usually changes in aggregate productivity cannot be completely explained by patterns of within-industry productivity growth.

There are many ways to measure the relative distance between production possibility frontiers (PPFs) attributable to growth of TFP, but two of them are especially relevant. Let Y^F be the vector of final outputs, M^M be the vector of imported intermediate inputs, and let L_t, K_t and N_t be the economy's endowments of primary factors of labour, capital and natural resources (land) at time t.[17] For purposes of exposition, it is convenient to assume that the economy is at a profit-maximizing point on its production possibility frontier, which rules out most kinds of disequilibria, and that aggregate technology exhibits constant returns to scale. Define the revenue function $R_t(L,K,N;P^F, P^M)$ as the function that gives the maximum value of revenue $P^F \cdot Y^F - P^M \cdot M^M$ achievable at prices (P^F, P^M) with the technology of period t and primary factor inputs (L,K,N). Then a measure of aggregate TFP based on final period prices and final period inputs is:

$$TFP^{Allen\text{-}Paashe} = R_t(L_t,K_t,N_t; P^F_t, P^M_t) \,/\, R_0(L_t,K_t,N_t; P^F_t, P^M_t)$$

$$= [R_t(L_t,K_t,N_t; P^F_t, P^M_t) \,/\, R_0(L_0,K_0,N_0; P^F_t, P^M_t)] \,/\, [R_0(L_t,K_t,N_t; P^F_t, P^M_t) / R_0(L_0,K_0,N_0; P^F_t, P^M_t)] \quad \text{(A1)}$$

The Paasche quantity index of GDP provides an upper bound estimate of the total change in output:[18]

$$(P^F_t \cdot Y^F_t - P^M_t \cdot M^M_t)/(P^F_t \cdot Y^F_0 - P^M_t \cdot M^M_0) \approx R_t(L_t,K_t,N_t; P^F_t, P^M_t) \,/\, R_0(L_0,K_0,N_0; P^F_t, P^M_t) \quad \text{(A2)}$$

If technology change has the same proportional effect on output when inputs are (L_t,K_t,N_t) as when they are (L_0,K_0,N_0) then:

$$R_t(L_t,K_t,N_t; P^F_t, P^M_t)/R_t(L_0,K_0,N_0; P^F_t, P^M_t) = R_0(L_t,K_t,N_t; P^F_t, P^M_t)/ R_0(L_0,K_0,N_0; P^F_t, P^M_t) \quad \text{(A3)}$$

Furthermore, if factors of production are paid their marginal revenue product, a Paasche quantity index of inputs will provide a lower bound approximation to $R_t(L_t, K_t, N_t; P^F_t, P^M_t)/ R_t(L_0,K_0,N_0; P^F_t, P^M_t)$. The Paasche quantity index of output divided by the Paasche quantity index of inputs is then an upper bound measure of the theoretical change in total factor productivity given by $TFP^{Allen\text{-}Laspeyres}$.

A symmetric analysis shows that under certain assumptions a Laspeyres quantity index is:

$$TFP^{Allen\text{-}Laspeyres} = R_t(L_0,K_0,N_0; P^F_0, P^M_0) \,/\, R_0(L_0,K_0,N_0; P^F_0, P^M_0)$$

$$= [R_t(L_t,K_t,N_t; P^F_0, P^M_0) \,/\, R_0(L_0,K_0,N_0; P^F_0, P^M_0)] \,/\, [R_t(L_t,K_t,N_t; P^F_0, P^M_0) \,/\, R_t(L_0,K_0,N_0; P^F_0, P^M_0)]$$

$$= [R_t(L_t,K_t,N_t; P^F_0, P^M_0) \,/\, R_0(L_0,K_0,N_0; P^F_0, P^M_0)] / [R_0(L_t,K_t,N_t; P^F_0, P^M_0) \,/\, R_0(L_0,K_0,N_0; P^F_0, P^M_0)] \quad \text{(A4)}$$

17 The time subscript on N could reflect exhaustion or new discoveries of mineral resources, or changes in the amount of land usable for agriculture caused by global warming.

18 Although the Paasche index is a lower bound in the theory of consumption price indexes, in the theory of output price indexes it is an upper bound. The quantity mix of the initial period may not be revenue-maximizing at the prices of the final period.

The Laspeyres quantity index of output is $(P_0^F \cdot Y_t^F - P_0^M \cdot M_t^M)/(P_0^F \cdot Y_0^F - P_0^M \cdot M_0^M)$. Under certain assumptions, dividing this index by a Laspeyres quantity index for inputs gives a theoretical lower bound for the conceptual measure given by $TFP^{Allen\text{-}Laspeyres}$. The Fisher index of TFP then has an appealing property as an average of upper and lower bounds for theoretical indexes.

Aggregate and Industry Level TFP in the Framework of the Domar Decomposition

Besides the final goods and services included in Y^F, industries also produce outputs that are used as intermediate inputs by themselves or by other industries. Assuming, for simplicity, that there are no taxes on products or tariffs, nominal GDP can be calculated as the sum of the value added of every industry. The Laspeyres (Paasche) volume measure of real GDP can also be calculated as the sum of industries' value added measured at initial (final) period prices.

The assumption that the economy is operating at a profit maximizing point on the PPF implies that at the margin reallocating inputs from one industry to another will not change the value of the revenue function. Hulten (1978) showed that in this framework the log change in aggregate TFP defined as an outward shift in the PPF can be calculated as a weighted sum of the log change in TFP of industries using the weights introduced by Domar (1961). The Domar weights add up to more than 1. Define Y_{i0} as the nominal gross output of industry i excluding intermediate inputs used within industry i and define G_0 as the total value added of all industries. Then industry i's Domar weight w_i^D equals Y_{i0} divided by aggregate value added G_0.

Let π^G be the Paasche index that measures period t prices relative to period 0 prices for G. Then the change in the Laspeyres quantity index for aggregate output, denoted $g^L(G)$, is:

$$g^L(G) = \frac{G_t/\pi^G - G_0}{G_0} \qquad \text{(A5)}$$

To define the aggregate quantity index of primary inputs used in the Domar decomposition I_t we must either treat detailed inputs used by different industries as different items, or assume that detailed inputs receive the same wage (or returns) everywhere they are employed. (If inputs in different industries are treated as different items in the quantity index of aggregate inputs, when labour is reallocated from a low wage industry to a high wage industry, the weight on the increase in labour in the high wage industry will be greater than the weight on the decrease in labour in the low wage industry and the aggregate input quantity index will rise.) In addition, it is assumed that an industry's revenues from sales of output are all used to acquire intermediate inputs or pay factors of production. Thus, if J_{i0} denotes the cost of the intermediate inputs that industry i obtains from other industries plus the cost of the primary inputs employed in industry i, $J_{i0} = Y_{i0}$. Let the Laspeyres measure of the growth rate of aggregate primary inputs I be $g^L(I) = (I_t/\pi^I - I_0)/I_0$, where π^I is a Paasche price index for inputs. Then the Laspeyres quantity index measure of aggregate TFP is

$$\begin{aligned} TFP^{Laspeyres} &= \frac{g^L(G) - g^L(I)}{1 + g^L(I)} \\ &\approx g^L(G) - g^L(I) \\ &= \textstyle\sum_i w_i^D \; [g^L(Y_i) - g^L(J_i)] \\ &= \textstyle\sum_i w_i^D \; TFP_i^{Laspeyres} \end{aligned} \qquad \text{(A6)}$$

In the framework of the Domar decomposition, an industry's own TFP growth times its Domar weight gives its contribution to aggregate TFP growth.

Appendix 2

Index of Labour Inputs that uses Compensation to Weight Industry-Occupation Cells

In a competitive neo-classical equilibrium, the marginal revenue product of a labour input is equal to the amount that the employer has to pay in compensation costs (wage plus benefits and social contributions) to employ the labour. However if labour is treated as a homogeneous input, the formula for the contribution of labour reallocation to aggregate productivity growth must assume that the marginal product of labour varies in direct proportion to its average product as measured by the ratio of real value added to the quantity of labour inputs used. Furthermore, differences in pay levels across industry-occupation cells may reflect differences in training, aptitude and experience. If so, industry-occupation cells should be treated as different kinds of inputs. When this is done, the role of reallocation effects (which are a kind of residual that cannot be explained by within-industry productivity growth) may be reduced.

To calculate a Laspeyres quantity index for labour inputs, let B_{it} be the nominal wage bill in year t (for convenience, we use "wages" as equivalent to compensation costs). Also, let W_t^P be the aggregate Paasche price index for wages and let W_{it}^P be the Paasche index of wages. The Laspeyres volume of labour inputs at time t is, then,

$$\hat{B}_t = \Sigma_i B_{it}/W_{it}^P$$

$$= \Sigma_i \hat{B}_{it}$$

$$= B_t / W_t^P \qquad \text{(A7)}$$

Let $\hat{b}_{it} = b_{it}(W_t^P / W_{it}^P) = (B_{it} / W_{it}^P)/(B_t / W_t^P)$, the share of the aggregate wage bill paid by industry i if the wage rates of year 0 had prevailed in year t, and let $b_{i0} = B_{i0} / B_0$, the industry i's share of the aggregate wage bill in year 0. Also, let $\hat{Z}_{it} = (V_{it}/P_{it}^P)/(B_{it}/W_{it}^P)$, the Laspeyres volume measure of labour input productivity. Letting $V_t = \Sigma_i V_{it}$ be nominal GDP at time t and $\hat{V}_t = V_t/P_t^P$, the change in the aggregate measure of Laspeyres labour input productivity is:

$$\frac{\hat{V}_t/\hat{B}_t}{V_0/B_0} - 1 = (\hat{Z}_t - \hat{Z}_0)/\hat{Z}_0$$

$$= \Sigma_i [\hat{b}_{it} \hat{Z}_{it} - b_{i0}\hat{Z}_{i0}]/\hat{Z}_0$$

$$= \Sigma_i [0.5(b_{i0} + \hat{b}_{it})(\hat{Z}_{it} - \hat{Z}_{i0}) + 0.5(\hat{Z}_{i0} + \hat{Z}_{it})(\hat{b}_{it} - b_{i0})]/\hat{Z}_0$$

$$= \Sigma_i 0.5(1+\hat{b}_{it}/b_{i0})g(\hat{Z}_i) + \Sigma_i [0.5(\hat{Z}_{i0} + \hat{Z}_{it}) / \hat{Z}_0](\hat{b}_{it} - b_{i0})$$

$$= \Sigma_i 0.5(1+\hat{b}_{it}/b_{i0})g(\hat{Z}_i) + \Sigma_i [0.5(\hat{Z}_{i0} + \hat{Z}_{it} - (\hat{Z}_0 + \hat{Z}_t))/\hat{Z}_0](\hat{b}_{it} - b_{i0}) \qquad \text{(A8)}$$

The contribution to aggregate Laspeyres labour input productivity growth from within-industry labour input productivity growth in industry i is:

$$c_i^{L-D} = 0.5(1+\hat{b}_{it}/b_{i0})g(\hat{Z}_i) \qquad \text{(A9)}$$

The contribution of reallocation of labour inputs to or from industry i to aggregate Laspeyres labour input productivity growth is therefore:

$$c_i^{L-R} = [0.5(\hat{Z}_{i0} + \hat{Z}_{it} - (\hat{Z}_0 + \hat{Z}_t))/\hat{Z}_0](\hat{b}_{it} - b_{i0}) \qquad \text{(A10)}$$

To derive the Paasche volume index of labour inputs, let W_{it}^L be the Laspeyres index of wages in industry i, and let W_t^L be the aggregate Laspeyres index of wages. Also, let $\hat{b}_{i0}$ be the share of the aggregate wage bill that would have been paid by industry i had the prices of period t prevailed in period 0

$$\hat{b}_{i0} = b_{i0}(W^L_{it}/W^L_t) \quad \text{(A11)}$$

Then the labour inputs productivity level of industry i in period 0 measured at prices of period t is:

$$\hat{z}_{i0} = \frac{V_{i0}(P^L_{it}/P^L_t)}{B_{i0}(W^L_{it}/W^L_t)} \quad \text{(A12)}$$

and the aggregate Paasche volume productivity equals:

$$\hat{z}_0 = V_0/B_0$$

$$= \sum_i \hat{b}_{i0}\ \hat{z}_{i0} \quad \text{(A13)}$$

Now let $\hat{z}_{it} = (V_{it}/B_{it})(W^L_t/P^L_t)$, a normalized ratio of value added to total wages in industry i, and let $\hat{z}_t = (V_t/B_t)(W^L_t/P^L_t)$ denote aggregate labour input productivity in period t. If A_0 is the aggregate ratio of output to labour inputs measured in current dollars in the base period, the aggregate Paasche volume measure of labour input productivity is:

$$\frac{(V_t/P^L_t)(B_t/W^L_t)}{V_0/B_o} - 1 = \frac{\hat{z}_t - \hat{z}_0}{\hat{z}_0}$$

$$= \frac{\Sigma_i b_{it}\hat{z}_{it} - (\hat{b}_{i0}\hat{z}_{i0})}{\hat{z}_0}$$

$$= \sum_i [0.5(\hat{b}_{i0} + b_{it})(\hat{z}_{it} - \hat{z}_{i0}) + 0.5(\hat{z}_{i0} + \hat{z}_{it})(b_{it} - \hat{b}_{i0})]/\hat{z}_0$$

$$= \sum_i 0.5(1 + b_{it}/\hat{b}_{i0})g(\hat{z}_i) + \sum_i [0.5(\hat{z}_{i0} + \hat{z}_{it})/\hat{z}_0](\hat{b}_{it} - b_{i0})$$

$$= \sum_i 0.5(1 + b_{it}/\hat{b}_{i0})g(\hat{z}_i) + \sum_i [0.5(\hat{z}_{i0} + \hat{z}_{it} - (\hat{z}_0 + \hat{z}_t))/\hat{z}_0](\hat{b}_{it} - b_{i0}) \quad \text{(A14)}$$

The contribution to aggregate Paasche labour input productivity growth from within-industry labour input productivity growth in industry i is:

$$c_i^{P-D} = 0.5(1 + b_{it}/\hat{b}_{i0})g(\hat{z}_i) \quad \text{(A15)}$$

The contribution of reallocation of labour inputs to or from industry i to aggregate Laspeyres labour input productivity growth is therefore:

$$c_i^{P-R} = [0.5(\hat{z}_{i0} + \hat{z}_{it} - (\hat{z}_0 + \hat{z}_t))/\hat{z}_0](b_{it} - \hat{b}_{i0}) \quad \text{(A16)}$$

Finally, we can use λ from equation (10) to define Fisher index contributions to aggregate labour inputs productivity change. The direct Fisher contribution of within-industry productivity growth is then seen to be:

$$c_i^{F-D} = \lambda c_i^{L-D} + (1-\lambda) c_i^{P-D}$$

$$= \lambda 0.5(1 + \hat{b}_{it}/b_{i0})g(\hat{Z}_i) + (1-\lambda)0.5(1 + b_{it}/\hat{b}_{i0})g(\hat{z}_i)$$

$$= 0.5[1 + \lambda(\hat{b}_{it}/b_{i0})g(\hat{Z}_i) + (1-\lambda)(b_{it}/\hat{b}_{i0})g(\hat{z}_i)] \quad \text{(A17)}$$

The contribution of reallocation of labour inputs involving industry i to Fisher labour inputs productivity is then:

$$c_i^{F-R} = \lambda c_i^{L-R} + (1-\lambda) c_i^{P-R}$$

$$= 0.5[\lambda[(\hat{Z}_{i0} + \hat{Z}_{it} - (\hat{Z}_0 + \hat{Z}_t))/\hat{Z}_0](\hat{b}_{it} - b_{i0}) + (1-\lambda)[(\hat{z}_{i0} + \hat{z}_{it} - (\hat{z}_0 + \hat{z}_t))/\hat{z}_0](b_{it}/\hat{b}_{i0})]] \quad \text{(A18)}$$

Closing the Aboriginal Education Gap in Canada: The Impact on Employment, GDP, and Labour Productivity

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ABSTRACT

Despite improvements between 2001 and 2011, Canada's Aboriginal population continues to underperform in the labour market. The Aboriginal educational attainment gap is often seen as the major source of these disparities. Using data from the 2011 National Household Survey, projections of Aboriginal population growth, and forecasts of aggregate economic conditions, we estimate the economic impact of closing the educational attainment gap by 2031. We find that the benefits of achieving such a feat could be very large, both for the Aboriginal population and for the country as a whole. Closing the education gap would raise Aboriginal employment by 90 thousand workers, GDP by $28.3 billion (2010 dollars) and Aboriginal employment income by $11,236 per worker in 2031. Labour productivity would increase by 0.03 percentage points per year over the 2011-2031 period. Assuming improvement occurs at a constant pace, we estimate that the cumulative gains to Canadian GDP would be as large as $261 billion (2010 dollars) over the 2011-2031 period.

THE ECONOMIC AND SOCIAL outcomes of Canada's Aboriginal people lag far behind those of the population more generally. This situation is costly not only for the Aboriginal population, but for the country as a whole.

Canada has struggled to keep up with other developed countries in terms of labour productivity performance in recent years. Between 2000 and 2014, labour productivity growth in the Canadian business sector was about 1.0 per cent annually, as measured by GDP per hour. This was far below the rate of 2.2 per cent annually in the United States over the same period and the rate of 1.5 per cent experienced in Canada between 1980 and 2000.[2] The low education levels of Canada's Aboriginal population offer an opportunity to improve our labour productivity performance by increasing the human capital of Aboriginal Canadians. Greater levels of educational attainment for Aboriginal Canadians would also boost employment rates. Both higher productivity and higher employment rates increase output.

1 Matthew Calver is an economist with the Centre for the Study of Living Standards (CSLS). This article is an abridged version of Calver (2015) which is publicly available on-line. The author would like to thank Andrew Sharpe, Don Drummond, Bert Waslander, David Johnson, and officials from Aboriginal Affairs and Northern Development Canada (AANDC), particularly John Clement, for comments. The CSLS gratefully acknowledges financial support from AANDC. Email: matthew.calver@csls.ca

2 Author's calculations using data from the CSLS Aggregate Income Trends: Canada vs. United States database, Table 6, available at www.csls.ca/data/ipt1.asp.

Previous research conducted at the Centre for the Study of Living Standards (CSLS) examined the potential economic benefits of eliminating the educational attainment gap. Sharpe et al. (2007) estimated that if the Aboriginal population achieved the same levels of educational attainment by 2017 as observed in the non-Aboriginal population in 2001, this would result in a cumulative increase in GDP of $71 billion (2001 dollars) over the 2001-2017 period. A follow-up study (Sharpe *et al.*, 2009) estimated that the benefits from closing this gap over a longer period (2001-2026) could be as high as $179 billion.

This article builds upon these studies to provide new estimates of the benefits of closing the Aboriginal educational attainment gap between 2011 and 2031. The methodology of these previous studies is extended to control for several important demographic characteristics (age, sex, and province/territory). This study also projects improvements in Aboriginal and non-Aboriginal education between 2011 and 2031 based upon recent trends in educational attainment (rather than assuming education levels remain unchanged). Calver (2015) provides breakdowns of the estimated benefits for several subpopulations of interest (sex, province/territory, and Aboriginal identity group).

This article is organized as follows: the first section provides descriptive information on the size of the Aboriginal education gap in 2011 and how it changed since 2001; the second section discusses how education affects individual and aggregate economic performance; the third section documents the educational attainment gap in Canada and how it relates to labour market gaps; the fourth section presents the data and methodology which are used to estimate the benefits of closing the education gap by 2031; the fifth section presents our estimates; the sixth section concludes.

The Aboriginal Labour Market Gaps

On average, Aboriginal people in Canada are less likely to be working than non-Aboriginal people and, if they are working, Aboriginal people tend to earn lower incomes. We will briefly describe the labour market gaps facing the Aboriginal population based on data collected from the 2011 National Household Survey (NHS).

We define the gaps in both absolute and relative terms. We define the absolute gap facing the Aboriginal population as the difference between the values for the non-Aboriginal and Aboriginal populations. We define the relative gap as the absolute gap expressed as a percentage of the non-Aboriginal value.

Table 1 presents the gaps for the national population aged 25-64 in 2011.[3] We restrict attention to this age group to exclude the working age population which is still in school (education is ongoing for this group and many remain out of the workfroce). This allows us to avoid some of the differences arising from the fact that the Aboriginal population is relatively young. We also exclude those above retirement age, as many of those above the age of 65 are no longer in the workforce.

The gap between the two populations in terms of employment rates is striking. Only 62.5 per cent of the Aboriginal population aged 25-64 was employed in 2011, 13.3 percentage points less than the 75.8 per cent non-Aboriginal employment rate. This employment rate gap

3 Note that the estimates presented in Table 1 have not been adjusted for differences in characteristics between the Aboriginal and non-Aboriginal populations. Much of these gaps can be explained by demographic and geographic differences between the Aboriginal and non-Aboriginal populations. In particular, the Aboriginal population tends to be younger and more concentrated in rural areas. Aboriginal labour market gaps persist even if many of these observable characteristics are controlled for. See, for example, Pendakur and Pendakur (2011).

Table 1
Aboriginal Labour Market Outcomes and Gaps, Ages 25-64, Canada, 2011

Labour Market Outcome	Aboriginal	Non-Aboriginal	Absolute Gap (Percentage Points)	Relative Gap (Per Cent)
Employment Rate (per cent)	62.5	75.8	13.3	17.5
Participation Rate (per cent)	71.7	80.6	8.9	11.0
Unemployment Rate (per cent)	12.8	6.0	-6.8	-113.3
Average Employment Income of Full-Year Full-Time Workers (2010; 2010 Constant Dollars)	$50,928	$60,296	$9,368	15.5

Source: Author's calculations using data from the National Household Survey, 2011.

arises because fewer Aboriginal people are active in the labour force and those who are in the labour force are less likely to be working.

The absolute labour force participation rate gap was 8.9 percentage points in 2011: 71.7 per cent of the Aboriginal population was working or seeking work compared to 80.6 per cent of the non-Aboriginal population. While this is a sizable gap, it is the smallest in relative terms of the four gaps we consider. The Aboriginal unemployment rate of 12.8 per cent in 2011 was more than double the non-Aboriginal unemployment rate of 6.0 per cent.

Lastly, we consider the employment income earned by those who are employed. To avoid some potential differences arising due to the number of hours worked, we restrict our attention to the incomes of full-year full-time (FYFT) workers.[4] The average employment income of a FYFT Aboriginal worker aged 25-64 was $50,928 in 2010 compared to an average employment income of $60,296 in the same category of non-Aboriginal workers. The gap is $9,368, which is 15.5 per cent of non-Aboriginal earnings from employment. To the extent that this employment income gap reflects differences in labour productivity, it implies that Aboriginal workers are lowering Canadian labour productivity on average.

The good news is that these gaps appear to be shrinking over time. Table 2 shows how absolute gaps have changed between 2001 and 2011. With the exception of the labour force participation gap, which only shrank 0.3 percentage points, significant improvements occurred. The employment rate gap was reduced by 3.3 percentage points, the unemployment rate gap by 4.5 percentage points, and the FYFT average income gap by $1,962 dollars.

These diminishing gaps are encouraging, but should be viewed cautiously. Demographic developments and geography may explain some of these improvements.[5] The samples underlying the Aboriginal and non-Aboriginal populations in the 2001 Census and 2011 National Household Survey have also changed, as a significant number of individuals changed their reported Aboriginal identity between 2001 and 2011. This phenomenon is known as intragenerational ethnic mobility.[6] If the large number of individuals who reported a non-Aboriginal identity in the 2001 Census and changed their reported identity to Aboriginal in the NHS had

4 Full-year full-time workers are those who worked between 49 and 52 weeks in the previous year and worked 30 hours or more for most of those weeks.

5 For example, the Aboriginal population is relatively concentrated in the western provinces which thrived economically during the oil boom.

6 For an analysis of Aboriginal ethnic mobility, see Caron-Malenfant *et al.* (2014)

Table 2

Changes in Aboriginal Labour Market Gaps, Ages 25-64, Canada, 2001-2011

Labour Market Outcome	Absolute Gap 2001	Absolute Gap 2011	Absolute Change in Absolute Gap, 2001-2011 (Percentage Points)	Relative Change in Absolute Gap, 2001-2011 (Per Cent)
Employment Rate (per cent)	16.6	13.3	-3.3	-19.9
Participation Rate (per cent)	9.2	8.9	-0.3	-3.3
Unemployment Rate (per cent)	-11.3	-6.8	4.5	-39.8
Average Employment Income of Full-Year Full-Time Workers (2010 Constant Dollars)	$11,330	$9,368	-$1,962	-17.3

Source: Author's calculations using data from the 2001 Census and the 2011 National Household Survey.

average non-Aboriginal characteristics, this will have resulted in a reduction in the gap. Furthermore, there are also concerns about selection arising from the replacement of the mandatory long form census with an optional survey.[7]

Even if all of this improvement were real, it is clear that the current level of Aboriginal labour market performance remains unsatisfactory. We will focus on one specific factor, education, which is frequently discussed in policy circles as a major source of these disparities.

Education and Labour Market Outcomes

The link between educational attainment and individual labour market outcomes has been well established in the literature.[8] The economic benefits of having a more educated population have also been documented at more aggregate levels, particularly in the context of economic development.[9] Notably, the aggregate national benefits are often found to exceed the total private benefits captured by individuals, suggesting that there are significant positive externalities associated with education.

Why does education have such a positive impact on individual economic outcomes? There are two major explanations.

The first explanation is that education raises human capital through developing knowledge, cognitive skills (math, literacy, and reasoning) (Ishikawa and Ryan, 2002; Heckman, 2006), and non-cognitive skills (e.g. interpersonal skills, organization skills) (Brunello and Schlotter, 2011). These improvements in human capital make the workforce more productive. This is typically the stated purpose of education.[10]

The second explanation is that the role of education is to screen individuals by signaling certain traits or abilities (Spence, 1973; Layard and Psacharopoulos, 1974). This view suggests that the value of a credential is not derived from what individuals have learned in earning it so much as from the evidence it provides of pre-existing attributes which allowed the individual to earn the credential

7 For example, if very high income and very low income individuals systematically underreported in the NHS, and if there are relatively more very low income Aboriginal people and very high income non-Aboriginal people, the income gap may appear to be reduced as a result of the changed methodology.

8 Recent papers which have evaluated the private returns to investments in education include Boudarbat *et al.* (2010), Dickson and Harmon (2011), and Li *et al.* (2012).

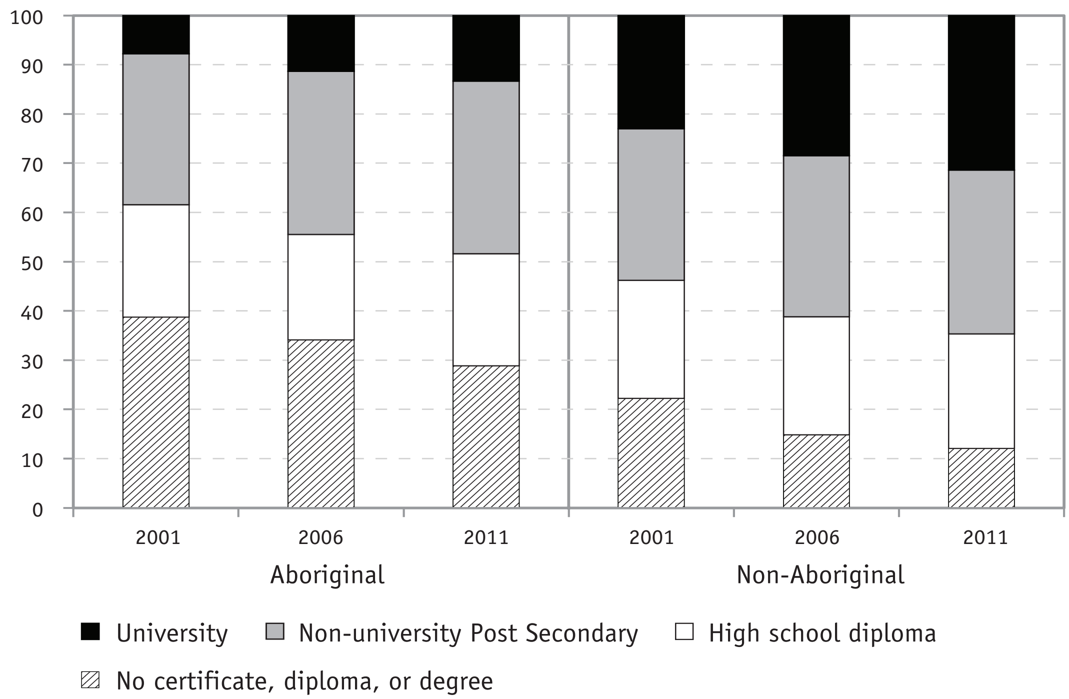
9 See, for example, Barro (2001), Cohen and Soto (2007), Shapiro (2006), and Aghion *et al.* (2009).

10 Hu (2014) analyzes the relationship between cognitive skills and Aboriginal wages and employment using 2012 Programme for International Assessment of Adult Competencies (PIACC) microdata. Hossain and Lamb (2012) find increased human and social capital raise Aboriginal employment incomes.

Chart 1

Highest Level of Educational Attainment, Ages 25-64, Aboriginal and Non-Aboriginal Populations, 2001, 2006, 2011

(per cent)



Source: Author's calculations using data from the 2001 Census, 2006 Census, and 2011 National Household Survey.

(hard work, perseverance, etc.). Under this theory, education is valuable because it assists firms in identifying productive workers. There is some empirical evidence supporting this view of education (Bedard, 2001; Hussey, 2012).

There is likely some truth to both the human capital and signaling approaches to education. Degrees in some fields, such as medicine or engineering, are valued largely for the knowledge and technical expertise developed through the program, while a general arts education may be valued more as a signal of general ability. Nonetheless, the distinction between these two views is worth considering because the underlying reason that education is valuable is important to forming sound education policy.[11]

While the signaling and human capital approaches may offer different recommendations regarding how to fix the problem, they

11 If education is valuable purely because it produces human capital, the emphasis should be on improving the quality and availability of Aboriginal education and removing impediments which are preventing Aboriginal students from acquiring these skills. If education is purely a signal, then the actual skills development and quality of education may not be so important. If Aboriginal youth possess the desired traits but employers are not receiving the correct signals, then changes to the education system should be made to address this. On the other hand, if Aboriginal youth are not earning the credentials that provide the correct labour market signals because they lack the desired traits, then the solution is to focus on the underlying social or cultural issues which are not producing these traits among the Aboriginal population rather than changing the education system itself. Eliminating the education gap without fixing underlying problems may be socially undesirable if education is primarily a signal – this would amount to lowering the standards required to earn a credential. This would reduce the quality of the signals, impeding efficient matching in the labour market and worsening average economic performance.

agree as to what the final outcome should look like: Aboriginal individuals should have a similar level of educational attainment to similar non-Aboriginal individuals on average.

Finally, we should note that the benefits of education extend far beyond labour market performance. Education is also associated with better health, reduced crime, political engagement (Lochner, 2011), and better financial decisions (Lusardi and Mitchell, 2013).

Aboriginal Education

Chart 1 illustrates the educational attainment distributions of Canada's Aboriginal and non-Aboriginal populations aged 25-64 in 2001, 2006, and 2011. Two major facts are evident from this chart. First, the Aboriginal population tends to be less educated. The differences arise largely at the extreme ends of the distribution. Only 12.1 per cent of the non-Aboriginal population lacked any certificate, diploma, or degree in 2011 compared to 28.9 per cent of the Aboriginal population. At the same time, only 13.4 per cent of the Aboriginal population held a university credential compared to 31.4 per cent of the non-Aboriginal population.

The second striking feature is that both Aboriginal and non-Aboriginal education have been rising over time. For example, the bottom category (no certificate, diploma, or degree) fell from 38.7 per cent of the Aboriginal population in 2001 to 28.9 per cent in 2011.[12]

For assessing overall changes in educational attainment it is convenient to adopt a summary measure. We use average years of educational attainment, reported in Table 3, as our summary measure. We have constructed the number of years of educational attainment for each of twelve distinct educational attainment categories based upon the average number of years of schooling of all individuals (Aboriginal and non-Aboriginal) possessing that credential in 2001.[13] This measure has been constructed using the Census and National Household Survey Public Use Microdata Files (PUMFs).

In 2011, average years of educational attainment for the Aboriginal population aged 25-64 was 12.7 while it was 14.1 years for the comparable non-Aboriginal population. This amounts to a gap of 1.4 years. This gap is largely unchanged from the gap of 1.3 years observed in 2001, despite the significant increase in Aboriginal educational attainment from 11.9 years to 12.7 over the period. This large improvement in education did not translate into a significantly reduced gap because the non-Aboriginal population experienced a very similar improvement over this period.[14]

Considering the educational attainment gaps in 2011 (Table 3), one notices a number

12 Changes in the Census questions regarding education between 2001 and 2006 make comparisons of educational attainment between 2001 and future years questionable. In particular, Statistics Canada cautions that high school completion had been underreported prior to the 2006 Census. This will explain some of the improvement from 2001 to 2006. See Calver (2015) for details.

13 Note that this measure only captures differences in the educational attainment distribution, but there can also be significant differences in terms of years of schooling between the Aboriginal and non-Aboriginal populations within educational attainment categories.Our measure may capture incomplete years or years towards credentials which were never completed. We have also generated similar results using assigned values for each educational attainment category based on the number of years we would expect that one would require to reach a given level of educational attainment (for example, high school would be 12 years). The level of years of educational attainment is lower under this alternative measure, but the estimates of the gaps and how they have changed over time remain qualitatively similar. Nationally, the absolute gap under this alternate measure increased very slightly from 1.28 years in 2001 to 1.30 years in 2011.

14 Note that a year of education at the high school level is not necessarily worth the same amount as a year of university education in terms of labour market outcomes, so the underlying changes in the educational attainment distribution may still have had an impact on the labour market gaps.

Table 3

Average Years of Educational Attainment of the Aboriginal and non-Aboriginal Populations Aged 25-64 by Select Characteristics, Canada, 2001, 2006, 2011

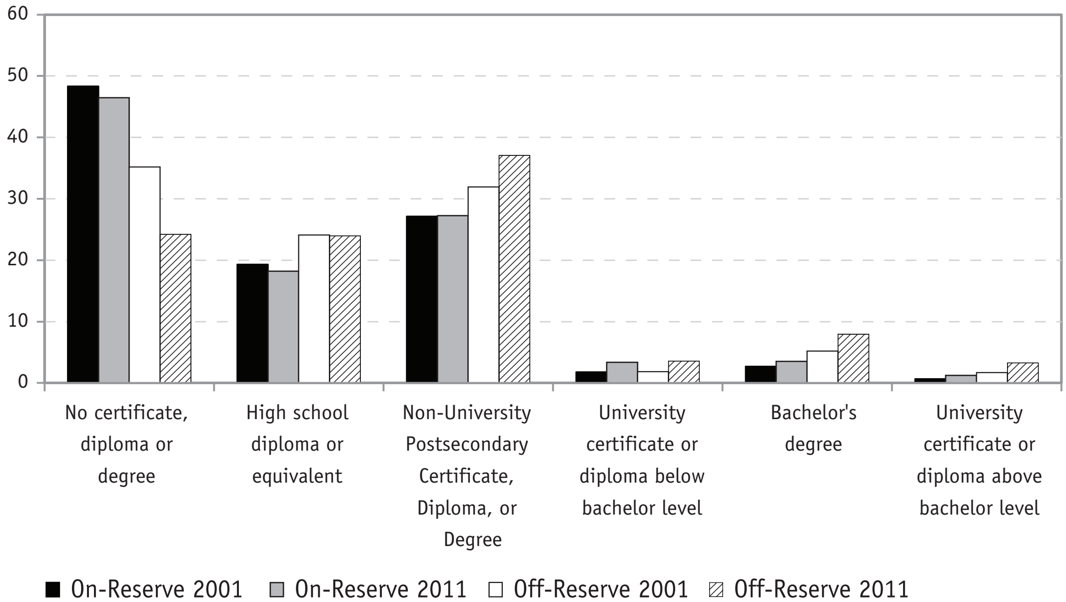
	2001			2006			2011		
	Aboriginal	Non-Ab-original	Absolute Gap	Aboriginal	Non-Ab-original	Absolute Gap	Aboriginal	Non-Ab-original	Absolute Gap
Canada	11.93	13.28	1.34	12.43	13.84	1.42	12.69	14.09	1.40
Newfoundland and Labrador	11.85	12.47	0.63	13.06	13.12	0.06	13.19	13.49	0.30
Prince Edward Island	11.64	12.80	1.16	12.95	13.43	0.48	13.57	13.71	0.14
Nova Scotia	12.25	13.04	0.79	12.40	13.57	1.17	13.32	13.88	0.56
New Brunswick	12.23	12.73	0.50	12.37	13.28	0.92	12.87	13.56	0.70
Quebec	11.91	13.19	1.28	12.77	13.74	0.97	12.78	13.95	1.17
Ontario	12.30	13.45	1.15	12.07	14.04	1.97	13.18	14.29	1.11
Manitoba	11.54	12.97	1.42	12.09	13.52	1.43	12.19	13.80	1.61
Saskatchewan	11.73	12.88	1.15	12.32	13.46	1.13	12.34	13.71	1.37
Alberta	11.89	13.23	1.34	12.52	13.74	1.22	12.45	14.02	1.57
British Columbia	12.01	13.41	1.40	11.85	13.94	2.09	12.80	14.17	1.37
Territories	11.65	13.99	2.34	11.33	14.26	2.92	11.52	14.49	2.97
Female	12.10	13.32	1.22	12.58	13.93	1.35	12.94	14.22	1.28
Male	11.75	13.23	1.47	12.19	13.75	1.56	12.42	13.96	1.54
Ages 25-34	12.04	13.80	1.76	12.42	14.23	1.81	12.66	14.41	1.75
Ages 35-44	12.04	13.39	1.35	12.46	14.02	1.56	12.94	14.37	1.43
Ages 45-54	11.97	13.21	1.24	12.46	13.64	1.18	12.71	13.97	1.26
Ages 55-64	11.26	12.44	1.18	12.21	13.37	1.16	12.41	13.61	1.20
First Nations	11.82	13.28	1.45	12.25	13.84	1.59	12.46	14.09	1.63
Métis	12.21	13.28	1.07	12.70	13.84	1.14	13.11	14.09	0.98
Inuit	11.44	13.28	1.84	11.58	13.84	2.27	11.56	14.09	2.53
Registered Indian Status	11.81	13.28	1.47	12.20	13.84	1.64	12.31	14.09	1.78

Source: Author's calculations using Public Use Microdata Files from the 2001 Census, 2006 Census, and 2011 National Household Survey.

of interesting patterns. The gap tends to be slightly larger for men than for women (1.54 years versus 1.28 years), for the young than for the old (1.75 years for those aged 25-34 vs. 1.20 years for those aged 55-64), and for registered Indians (1.78 years). The Métis (0.98 years) also fare better in terms of the gap than the First Nations (1.63 years) and the Inuit (2.53 years). Geographically, the gaps tend to be larger in the western provinces and in the Territories.

It is worth mentioning that educational attainment is especially low for the population living on-reserve. Chart 2 compares the Aboriginal educational attainment distributions on- and off-reserve in 2001 and 2011. One sees that the population living off-reserve was much better educated in 2001. Between 2001 and 2011, there were substantial improvements in education off-reserve while education levels on-reserve were relatively stagnant. For example, the bottom category (no certificate, diploma, or

Chart 2
Comparison of Highest Educational Attainment, Total Aboriginal Population On- and Off-Reserve, Ages 25-64, 2001 and 2011
(per cent)



Source: Author's calculations using data from the 2001 Census and 2011 National Household Survey.

degree) fell from 35.2 per cent to 24.2 per cent off-reserve, but only dropped from 48.4 per cent to 46.4 per cent on-reserve.

We have established that the Aboriginal population is relatively under-educated, but how does this relate to the labour market outcome gaps? Table 4 shows differences in our four labour market outcomes between the Aboriginal and non-Aboriginal populations conditional upon five levels of highest educational attainment. A number of interesting trends appear. Notice that the participation, unemployment, and employment rate gaps tend to be very large for those in the lowest education categories, but shrink considerably at higher levels of education. For example, the relative employment rate gap was 25.1 per cent for those with no certificate, diploma, or degree but only 1.7 per cent for those with a bachelor's degree. Perhaps surprisingly, this pattern does not hold for the employment income gap. We find that this gap was largest for those with a bachelor's degree (14.1 per cent), but there was virtually no gap for those with no certificate, diploma, or degree.

Notice that while the absolute gaps are sometimes large between the Aboriginal and non-Aboriginal populations, the differences across education levels within the Aboriginal population tend to be much larger. For example, Aboriginal people holding a bachelor's degree made $10,594 less than non-Aboriginal people holding a bachelor's degree on average in 2010, but they made $25,654 more than Aboriginal people with no certificate, diploma, or degree. This suggests that differences in educational attainment explain a substantial portion of the labour market outcome gaps.

What is driving the income and employment rate gaps within each educational attainment category? We will briefly touch upon the most obvious and important contributors which can be easily quantified, although there

Table 4
Aboriginal Labour Market Gaps by Education Level, Ages 25-64, Canada, 2011

Highest Level of Education Attained	Average Employment Income (Full-Year Full-Time Workers, 2010, Dollars)			Participation Rate (per cent)			Employment Rate (per cent)			Unemployment Rate (per cent)		
	Ab-original	Non-Ab-original	Relative Gap (%)	Ab-original	Non-Ab-original	Relative Gap (%)	Ab-original	Non-Ab-original	Relative Gap (%)	Ab-original	Non-Ab-original	Relative Gap (%)
None	38,735	38,919	0.5	54.0	64.2	15.8	42.9	57.3	25.1	20.6	10.7	-92.5
High School or Equivalent	43,563	47,030	7.4	74.1	78.2	5.2	64.8	72.8	11.0	12.5	6.9	-81.2
Postsecondary Below Bachelor's	51,650	53,343	3.2	81.3	85.3	4.7	73.1	80.5	9.2	10.2	5.7	-78.9
Bachelor's Degree	64,389	74,983	14.1	87.0	86.9	-0.1	81.7	83.1	1.7	6.0	4.4	-36.4
University Degree Above Bachelor's	96,032	91,215	-5.3	89.0	86.6	-2.7	85.6	82.5	-3.8	3.7	4.8	22.9
All Categories*	50,230	58,934	14.8	72.4	81.7	11.3	63.4	76.7	17.3	12.4	6.1	-103.3

* Note: While the values for all educational categories are similar to those presented in Table 1, they are not identical. This reflects the fact that the values in this table were estimated using the Public Use Microdata File.

Source: Author's calculations based on the Public Use Microdata File from the 2011 National Household Survey.

could be other relevant factors such as racial discrimination or occupational choices. Note that these factors are relevant for understanding the education gap both through their direct impacts on labour market outcomes given a level of education but also through their impacts on the educational attainment distribution.

Geographic differences between the two populations can generate differences in terms of economic opportunities. Employment rates and incomes tend to be higher in the western provinces, the Yukon, and the Northwest Territories. These are the regions where the Aboriginal population is overrepresented. This geographic distribution may dampen the full magnitude of the gaps.

The Aboriginal population also tends to be much more concentrated in rural areas, which typically offer fewer economic opportunities. 87.2 per cent of the non-Aboriginal population lived in Census Metropolitan Areas (CMAs) or Census Agglomerations (CAs) of 10,000 people or more in 2011 compared to 58.3 per cent of the Aboriginal population (Calver, 2015). This likely accounts for a significant portion of the poorer Aboriginal labour market performance within an educaitonal attainment category relative to the non-Aboriginal population.

Differences in age are another major source of differences in labour market performance. The Aboriginal population is younger than the non-Aboriginal population. The young tend to lack experience and consequently have more difficulty finding work and receive lower wages. As people approach retirement age, labour force participation rates diminish.

Potential Benefits from Closing the Gap: Data and Methodology

Now that we have examined the education and labour market gaps facing the non-Aboriginal population and some of the underlying demographic and geographic factors, we will estimate the economic benefits of closing the educational attainment gap.

Our exercise will be forward looking, as this is more relevant for policy decisions. We first construct a baseline projection of Aboriginal educational attainment, employment, and income in 2031.[15] We then compare these baseline outcomes to those under alternative assumptions regarding the extent to which the educational attainment gap and the employment rate and employment income gaps within education categories close. These estimates should be viewed as aspirational rather than as predictions of what is realistically feasible. Even our baseline projections assume that Aboriginal education will improve significantly, and it is in our view extremely unlikely that the gap could actually be closed in 20 years.[16]

First, we must describe the construction of our baseline projection. This projection represents our expectations of Aboriginal economic and educational outcomes in 2031 if recent trends persist. In order to construct this projection, we must estimate the future Aboriginal population and its educational attainment distribution, employment rates by education category, and incomes given education and employment.

We do not construct population projections. Instead, we use projections from "Population Projections by Aboriginal Identity in Canada, 2006 to 2031" (Malenfant and Morency, 2011) which were produced by Statistics Canada's Demosim Team based upon the estimated Aboriginal population in 2006. We use the projection which assumes constant fertility and no additional ethnic mobility after 2006. The projected Aboriginal population in 2031 is 1.734 million which was based upon a population of 1.279 million in 2006. Given that the NHS estimate of the Aboriginal population in 2011 was 1.401 million due in part to continued ethnic mobility, we view this population projection as very conservative.

The population projections are available by province of residence and by age and sex, but we do not possess an age/sex breakdown by province. As such, we assume that the age and sex distribution will be the same as the national distribution within each province in 2031.

To estimate economic outcomes at the national level and growth in real wages, we use economic projections from the Policy and Economic Analysis Program (PEAP) of the University of Toronto's Rotman School of Management (Dungan and Murphy, 2013). In particular, we rely upon forecasts of GDP (2.6 trillion 2010 dollars in 2031), real wage growth (41 per cent increase from 2010 to 2031)[17], and national employment (20.2 million workers in 2031). We only use the growth rate of real wages to directly estimate the benefits to the Aboriginal population. We assume that the baseline GDP and national employment correspond to those from the PEAP projections when estimating the impacts of closing the gaps on national outcomes.

Our projections of employment rates, educational attainment (9 education categories listed in Table 5), and employment incomes are based upon data in the 2011 National Household Survey Public Use Microdata File (NHS PUMF). All projections are made by age (we consider six age groups: 15-24, 25-34, 35-44, 45-54, 55-64 and 65+), sex, and province/territory of resi-

15 The estimates consider average income of all those with employment income, not just those who work FYFT. Note that this exercise includes the entire working age population (15+), as opposed to those aged 25-64 years, which we considred when illustrating the gaps.

16 If for no other reason, many of those aged 25-44 in 2011 will still be working in 2031. It is unlikely that many of these individuals will return to school.

17 This is an optimistic estimate given historical real wage growth. The compound average annual growth rate over the 2000-2010 period recorded in the PEAP projections was only approximately 0.85 per cent, compared to 1.65 per cent in PEAP projections for the 2010-2031 period.

Table 5

Projected Aboriginal and Non-Aboriginal Educational Attainment in 2031 Based on 2006-2011 Trends, Population Aged 15+

Highest Educational Attainment	Years Educational Attainment (2001)	Non-Aboriginal 2006 Share (%)	Non-Aboriginal 2011 Share (%)	Non-Aboriginal Compound Annual Growth Rate of Share (%)	Non-Aboriginal Adjusted 2031 Share (%) (Projected	Aboriginal 2006 Share (%)	Aboriginal 2011 Share (%)	Aboriginal Compound Annual Growth Rate of Share (%)	Aboriginal Adjusted 2031 Share (%) (Projected)
No certificate, diploma, or degree	9.29	23.10	19.45	-3.38	8.81	43.99	38.36	-2.70	18.70
High school graduation certificate or equivalency certificate	12.79	25.79	25.72	-0.05	22.94	21.72	24.45	2.40	33.12
Other trades certificate or diploma	12.92	10.86	10.77	-0.17	9.38	11.33	11.43	0.18	9.99
College, CEGEP or other non-university certificate or diploma from a program of 3 months to less than 1 year	12.06	2.27	2.27	0.09	2.08	-2.8	3.12	2.19	4.06
College, CEGEP or other non-university certificate or diploma from a program of 1 year to 2 years	14.68	8.32	8.67	0.84	9.23	7.78	8.44	1.64	9.85
College, CEGEP or other non-university certificate or diploma from a program of more than 2 years	15.73	6.85	7.40	1.56	9.08	3.92	4.47	2.67	6.38
University certificate or diploma below bachelor level	15.68	4.45	4.42	-0.10	3.90	2.76	2.44	-2.48	1.24
Bachelor's degree	16.42	11.90	13.70	2.86	21.69	4.18	5.45	5.47	13.33
Above Bachelor`s	17.44	6.47	7.58	3.23	12.89	1.53	1.85	3.86	3.33
Average Educational Attainment (Years)		13.20	13.46		14.42	11.81	12.08		13.17

Source: Author's calculations based on the 2011 National Household Survey Public Use Microdata File, the 2006 Census Public Use Microdata File and Aboriginal population projections from "Population Projections by Aboriginal Identity in Canada, 2006 to 2031," Statistics Canada, Demography Division.

dence.[18] These projections consider the entire working age population (ages 15+).

The projections of employment rates and employment incomes are very straightforward. The baseline Aboriginal employment rate in 2031 is assumed to be exactly the same as that observed in the 2011 NHS PUMF (for a given age, sex, province/territory, and education).

Similarly, the baseline Aboriginal employment income in 2031 is assumed to be the same as that observed among those employed in the 2011 NHS PUMF (conditional upon age, sex, province/territory, and education),[19] scaled up by the projected national growth in real wages of 41 per cent. We are assuming that real wage growth occurs at a uniform rate across the entire population.

To estimate the educational attainment distribution in 2031, we assume that the population share in each educational attainment category will continue to grow at the compound annual rate observed between the 2006 Census and the 2011 NHS (Table 5). For example, the bottom category of no certificate, diploma, or degree shrank from 44.0 per cent of the Aboriginal population aged 15+ in 2006 to 38.4 per cent in 2011. If this compound avergae annual growth rate of -2.7 per

18 The territories are combined. Note that our geographic controls assume that individuals do not move when they attain a higher level of education.

19 These projections are quite demanding of the data available to us. Given the limited sample size of the PUMF, one may be concerned about the accuracy of these estimates for smaller subpopulations, but the aggregate estimates which we are considering should be reasonable.

Box 1

Summary of Assumptions

Given our baseline projections of Aboriginal and non-Aboriginal outcomes in 2031, the scenarios we consider can be summarized by a set of assumptions regarding what happens to the educational attainment gap, the average employment income gap, and the employment rate gap. The assumptions are as follows:

The Educational Attainment Gap

- Projected 2031 gap unchanged: The share of the Aboriginal population in each educational attainment category in 2031 is identical to the projected share of the Aboriginal population in that educational attainment category in 2031.
- Entire projected 2031 gap eliminated: The share of the Aboriginal population in each educational attainment category in 2031 is identical to the projected share of the non-Aboriginal population in that educational attainment category in 2031.

The Average Income Gap (Conditional on Education)

- 2010 gap unchanged by 2031: The average real income of an employed Aboriginal person with a given level of education in 2031 is assumed to equal that of an employed Aboriginal person with the same level of education in 2010, increased at the average rate of real wage growth predicted by the PEAP forecast.
- Entire 2010 gap eliminated by 2031: The average real income of an employed Aboriginal person with a given level of education in 2031 is assumed to equal that of an employed non-Aboriginal person with the same level of education in 2010, increased at the average rate of real wage growth predicted by the PEAP forecast.

The Employment Rate Gap (Conditional on Education)

- 2011 gap unchanged by 2031: The employment rate of an Aboriginal person with a given level of education in 2031 is assumed equal to that of an Aboriginal person with the same level of education in 2011.
- Entire 2011 gap eliminated by 2031: The employment rate of an Aboriginal person with a given level of education in 2031 is assumed equal to that of a non-Aboriginal person with the same level of education in 2011.

cent was applied for the next 20 years, the share of the population in this category would be about 22.2 per cent by 2031. Of course, this approach will produce a set of shares of the population by educational attainment that do not sum to one, so they must be normalized (after normalizing, the 22.2 per cent becomes 18.7 per cent). We do not calculate the growth rates within each age-sex-province group, but rather assume that the national growth rates for the share in each educational category apply to the entire population.[20]

20 This is not the most accurate method for projecting the educational attainment distribution. A more appropriate approach would be to construct cohort based projections using a model of the transition rates from one educational attainment category to another over the life cycle.

Once we have our baseline projection, we construct a series of alternative projections, characterized by the assumptions summarized in Box 1. These involve projecting the comparable educational attainment distributions, employment rates, and average employment incomes of the non-Aboriginal population. We estimate the benefits of closing the gaps by comparing what would happen if the projected Aboriginal population achieved the projected non-Aboriginal outcomes.

This brings us to the central assumption of this exercise. We assume that if an individual with a given level of education achieves a higher level of education, then that individual will be expected to achieve the same outcomes on average as the comparable population (in terms of age, sex, and province/territory) which had already achieved the higher level of education. This assumption is strong and is unlikely to hold in reality. In particular, one should be concerned that there may be selection into education or omitted variables which play a role in educational outcomes, but which we fail to take into consideration.

It might be the case that individuals who expect higher returns to education, due to personal characteristics, are more likely to invest in it. For example, if Aboriginal university graduates tend to be harder working or more talented on average than those with only a high school diploma, than they may overrepresent the average returns to education for the general population. This could bias our estimates upwards.

We know of at least one variable which we do not control for which will probably make the returns to education lower than we assume: the fraction of the population living in remote or rural areas. Aboriginal people in rural areas tend to be less educated and have worse labour market outcomes than Aboriginal people living in urban areas. Suppose most of the improvement in education occurs in rural areas. If these individuals stay in rural areas, one would expect that they will obtain the returns to education of those in rural areas which will be lower than those of the total population, but our assumption is that these individuals will achieve the returns to education of the total population. One way to interpret our assumption is that migration to urban areas will occur such that the returns to education are equal to those of the general population.

We have estimated the labour market outcomes under all combinations of the assumptions listed in Box 1.[21] We present the benefits from entirely eliminating each of the three gaps separately, and eliminating all three gaps simultaneously in this article (see Calver (2015) for other scenarios). By comparing the appropriate scenarios, one can estimate the effects of closing the educational attainment gap under various assumptions regarding the employment rate and income gaps conditional upon education.

Once we have estimates of the benefits for the Aboriginal population in terms of employment and average income, we can estimate the impact on the Aboriginal contribution to GDP by multiplying employment by average employment income and then doubling this figure to reflect that only about half of GDP in Canada is earned by workers in the form of employment income.

The increases in Aboriginal employment and contributions to GDP can be added to the baseline (PEAP) national projections to estimate the potential impact on the growth rates of Canadian GDP, employment, and labour productivity.

As all calculations occur within age-sex-province groupings, it is straightforward to decompose our estimates of the national benefits by sex, age group, and province. Additionally, we have also estimated the benefits for the three single response Aboriginal identity groups (First Nations, Métis, and Inuit), for those living on-

21 Calver (2015) also examines labour market outcomes under the additional assumption of the education gap half closing.

Table 6

Projected Increase in Aboriginal Employment under Various Scenarios Relative to Baseline Scenario, 2031

(thousands)

Province	Absolute Change over Baseline					Relative Change over Baseline (%)	
	Baseline (2031 Level)	Employment Rate Gap Closes	Income Gap Closes	Education Gap Closes	All Three Gaps Close	Education Gap Closes	All Three Gaps Close
Newfoundland and Labrador	8.1	0.9	0.00	1.0	1.0	11.7	12.5
Prince Edward Island	0.8	0.10	0.00	0.3	0.2	39.0	26.0
Nova Scotia	13.5	0.8	0.00	1.0	1.3	7.9	9.7
New Brunswick	7.0	1.6	0.00	0.9	2.0	13.0	28.0
Quebec	74.8	6.8	0.00	5.5	11.3	7.3	15.2
Ontario	148.9	10.2	0.00	12.4	17.6	8.3	11.8
Manitoba	109.0	17.0	0.00	15.0	23.6	13.7	21.5
Saskatchewan	87.0	31.1	0.00	11.6	34.8	13.4	40.1
Alberta	135.2	15.1	0.00	15.2	22.2	11.2	16.4
British Columbia	115.0	13.2	0.00	16.1	19.1	14.0	16.6
Territories	27.3	12.0	0.00	11.0	12.3	40.2	45.0
Canada	727.0	108.9	0.00	90.0	145.4	12.4	20.0

Source: Author's calculations based on the 2011 National Household Survey Public Use Microdata File and Aboriginal population projections from Population Projections by Aboriginal Identity in Canada, 2006 to 2031, Statistics Canada, Demography Division.

and off-reserve, and for those with and without registered Indian status.[22] We only present the national and provincial results in this article. See Calver (2015) for further breakdowns of the benefits.

Potential Benefits from Closing the Gap: Results

We project that the average number of years of educational attainment of the Aboriginal population will rise from 12.7 years in 2011 to 13.0 years in 2031.[23] Notice that this is an optimistic baseline scenario, particularly at the upper and lower ends of the distribution, as it assumes that improvements will proceed at the high rates observed between 2006 and 2011. For example, this projection would see the share of the Aboriginal population in the bottom category (no certificate, diploma, or degree) decrease from 38.4 per cent to 22.0 per cent, while the share with a bachelor's degree as the highest level of education would rise from 5.5 per cent to 12.2 per cent. If the educational attainment gap were eliminated (conditional on age, sex, and province), then 10.1 per cent of the population would be in the bottom category and 21.5 per cent would be in the bachelor's degree category.

Table 6 presents our estimates of the impact of closing the gaps on Aboriginal employment.

22 Estimates of the benefits of closing the educational attainment gap for the on- and off-reserve First Nations populations and for the populations with and without registered Indian status were made using several additional assumptions (Calver, 2015).

23 While they are similar, the figures in this paragraph are not quite the same as the projected shares or average years of educational attainment reported in Table 5. The values in Table 5 are projected nationally with no controls for the demographic and geographic structure of the Aboriginal population. In contrast, the figures presented here incorporate our projected age-sex-province distribution of the Aboriginal population in 2031.

Table 7
Projected Increase in Aboriginal Average Employment Income over Baseline Scenario, 2031
(2010 dollars)

	Absolute Change over Baseline					Relative Change over Baseline (%)	
Province	Baseline (2031 Level)	Employment Rate Gap Closes	Income Gap Closes	Education Gap Closes	All Three Gaps Close	Education Gap Closes	All Three Gaps Close
Newfoundland and Labrador	$68,989	-$571	-$5,547	$9,609	-$5,685	13.93	-8.24
Prince Edward Island	37,278	10,526	5,761	5,514	13,905	14.79	37.30
Nova Scotia	45,878	898	5,857	8,603	10,626	18.75	23.16
New Brunswick	42,400	2,658	7,984	5,107	14,925	12.04	35.20
Quebec	52,013	-1,388	730	7,337	6,577	14.11	12.64
Ontario	55,287	665	4,241	10,326	14,602	18.68	26.41
Manitoba	49,349	-1,707	3,672	10,600	9,419	21.48	19.09
Saskatchewan	53,101	-3,245	9,160	4,765	10,397	8.97	19.58
Alberta	66,449	-1,431	2,777	19,738	12,740	29.70	19.17
British Columbia	48,228	263	7,624	6,734	14,509	13.96	30.08
Territories	79,061	-6,884	-2,784	22,812	8,152	28.85	10.31
Canada	55,482	-1,063	4,340	11,236	11,623	20.25	20.95

Source: Author's calculations based on the 2011 National Household Survey Public Use Microdata File and Aboriginal population projections from Population Projections by Aboriginal Identity in Canada, 2006 to 2031, Statistics Canada, Demography Division.

Under the baseline scenario, we project that 727 thousand Aboriginal people will be employed in Canada in 2031. If the education gap were eliminated, we estimate that an additional 90 thousand Aboriginal people would be employed. As a point of comparison, closing the employment rate gap within each educational attainment category is estimated to increase employment by 109 thousand. If both the education and employment rate gaps closed simultaneously, we estimate that the total improvement would be 145 thousand workers, a 20 per cent increase over the baseline.[24]

We estimate that the gains from closing the educational attainment gap would be relatively larger for certain subpopulations. Geographically, the estimated gains to employment are very large in the Territories (45.0 per cent) and relatively small in Ontario (11.8 per cent) and Quebec (15.2 per cent).

Table 7 contains the absolute improvements in terms of average Aboriginal employment income (of those employed). We estimate that closing (only) the educational attainment gap would raise average employment income by $11,236 per Aboriginal worker over a baseline of $55,482 (2010 dollars). This is considerably greater than the estimated benefit of $4,340 from closing the income gap or the reduction of $1,063 from closing the employment rate gap.[25]

24 Notice that the total improvement is not the sum of the improvements from closing each gap separately. This is because there are interactions between closing the two gaps. For example, if the employment rate gap is much larger for those with low levels of education, then closing the employment rate gap conditional on education will have a much smaller effect if the educational attainment gap has been closed.

25 The reader may be wondering why closing the employment rate gap reduces average employment income. Recall that the largest employment rate gaps seem to occur among those with the lowest levels of education. These individuals also tend to earn the lowest incomes. As a result, closing the employment rate gap lowers the average income through a composition effect.

Table 8
Projected Increase in Aboriginal Contribution to GDP over Baseline Scenario, 2031
(billions, 2010 dollars)

	Absolute Change over Baseline					Change over Baseline	
Province	**Baseline (2031 Level)**	**Employment Rate Gap Closes**	**Income Gap Closes**	**Education Gap Closes**	**All Three Gaps Close**	**Education Gap Closes**	**All Three Gaps Close**
Newfoundland and Labrador	1.12	0.12	-0.09	0.31	0.04	27.68	3.57
Prince Edward Island	0.06	0.02	0.01	0.03	0.04	50.00	66.67
Nova Scotia	1.23	0.10	0.16	0.35	0.43	28.46	34.96
New Brunswick	0.59	0.18	0.11	0.16	0.43	27.12	72.88
Quebec	7.78	0.48	0.11	1.75	2.31	22.49	29.69
Ontario	16.47	1.34	1.26	4.70	6.81	28.54	41.35
Manitoba	10.81	1.25	0.80	4.12	4.83	38.11	44.68
Saskatchewan	9.23	2.54	1.59	2.18	6.23	23.62	67.50
Alberta	17.97	1.58	0.75	7.96	6.96	44.30	38.73
British Columbia	11.10	1.34	1.75	3.32	5.74	29.91	51.71
Territories	4.32	1.35	-0.15	3.48	2.59	80.56	59.95
Canada	80.67	10.31	6.31	28.34	36.41	35.13	45.13

Source: Author's calculations based on the 2011 National Household Survey Public Use Microdata File and Aboriginal population projections from Population Projections by Aboriginal Identity in Canada, 2006 to 2031, Statistics Canada, Demography Division.

Closing all three gaps is estimated to raise average employment income by $11,623.

Geographically, the increases in average employment income from closing the educational attainment gap are relatively large in Alberta (29.7 per cent) and the Territories (28.9 per cent), although they are estimated to be surprisingly low in Saskatchewan (9.0 per cent).

Table 8 combines the estimates underlying Table 6 and Table 7 to estimate the impact of closing the gaps on the Aboriginal contribution to GDP (estimated as employment multiplied by average employment income multiplied by 2). The baseline Aboriginal contribution to GDP is projected at $80.7 billion (2010 dollars). If the educational attainment gap were fully closed, this would significantly increase by an estimated $28.3 billion. For comparison, we estimate that closing the employment rate gap would raise the Aboriginal contribution to GDP by $10.3 billion while closing the income gap would increase it by only about $6.3 billion. The total benefits could be as large as $36.4 billion if all three gaps were eliminated.

The estimated relative benefits from closing the educational attainment gap are estimated to be the largest in the Territories by far (80.7 per cent), but are also very large in Alberta (44 per cent) and Manitoba (38.2 per cent). Even in provinces where the benefits are relatively small, such as Quebec (28.5 per cent) and Saskatchewan (23.6 per cent), they are still substantial.

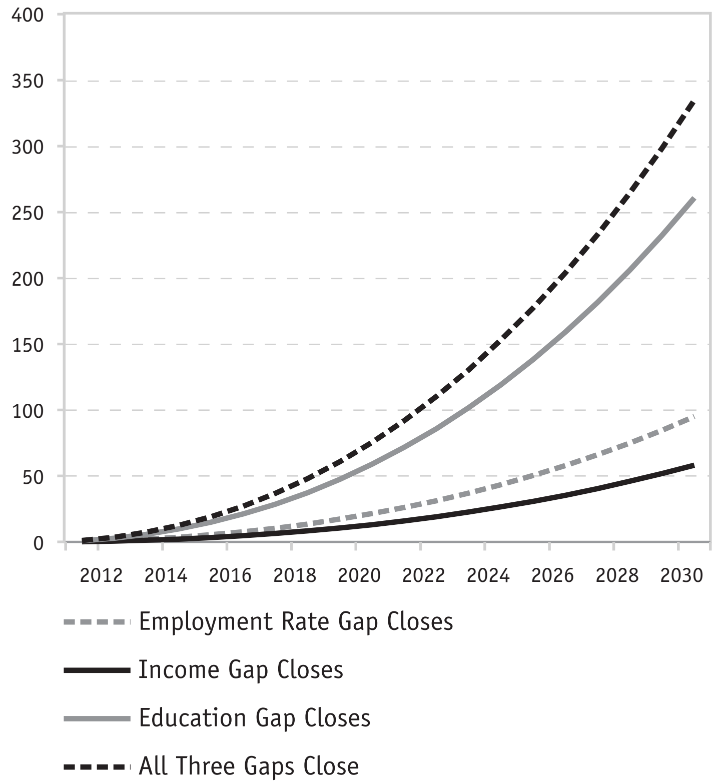
These improvements would benefit not only the Aboriginal population, but the Canadian economy more generally. Applying these improvements to the projected national economic outcomes from the PEAP, we estimate the impact on growth in Canadian employment, GDP, and labour productivity (Table 9). Since the only changes in employment and GDP are those associated with the Aboriginal population, the changes in national employment and GDP are exactly the same as those we have already discussed (Tables 6 and 8). These changes to employment and GDP result in changes to labour productivity nationally. Of course, the impact on aggregate labour productivity is much smaller than that on Aboriginal employment income because Aboriginal people make up a relatively small segment of the labour force. Nonetheless, closing the educational attainment gap would have a non-negligible impact on aggregate labour productivity, raising it by $820 or about 0.6 per cent of the baseline labour productivity of $129,781.

Our baseline projections indicate that employment will grow at a compound annual rate of 0.78 per cent, GDP at a rate of 2.17 per cent, and labour productivity at a rate of 1.38 per cent between 2011 and 2031. If (only) the educational attainment gap was closed, we estimate that these growth rates would increase by 0.0224 percentage points, 0.0549 percentage points, and 0.0320 percentage points respectively. These increases may not sound very large, but one needs to keep in mind that only 4.3 per cent of Canada's population reported an Aboriginal identity in the 2011 NHS.

How much is an increase in annual GDP growth of 0.0549 percentage points worth?[26] Chart 3 presents the gains as a result of this increase from 2011 to 2031. All figures are undiscounted. The cumulative value of eliminating the educational attainment gap is $261 billion (2010 dollars). Even closing the gap halfway would result in very large benefits of $130 billion (Calver, 2015), which is larger than the benefits of $95 billion from closing the employment rate gap or $58 billion from closing the employment income gap. Closing all three gaps could have a total economic impact as large as $335 billion over the 20-year period.

Chart 3

Estimated Cumulative Gains to Output from Closing the Aboriginal Education, Income, and Employment Rate Gaps (Billions of 2010 dollars), Canada, 2011-2031



Source: Author's calculations based on the 2011 National Household Survey Public Use Microdata File and Aboriginal population projections from Population Projections by Aboriginal Identity in Canada, 2006 to 2031, Statistics Canada, Demography Division. No discounting has been applied in these calculations.

Conclusion

While the economic disparities between Canada's Aboriginal and non-Aboriginal populations in terms of employment rates and employment incomes appear to have been shrinking since 2001, sizable gaps remain. Relatively low levels of educational attainment can explain a significant portion of these labour market gaps, suggesting that there could be large economic gains from further investments in improving Aboriginal education. We have

26 Note that in performing this calculation, we are assuming a very specific path in terms of how the benefits will occur over time (constant growth). There is no reason to think that this is the correct growth path, we are only using it to provide a ballpark estimate as to what the cumulative benefits could be.

Table 9

Projected Aggregate Employment, GDP, and Labour Productivity Outcomes with Closure of Aboriginal Education, Income and Employment Rate Gaps, Canada, 2031

	2011	Baseline (2031)	Employment Rate Gap Closes	Income Gap Closes	Education Gap Closes	All Three Gaps Close
Aggregate Levels, Increase over Baseline						
Employment (thousands)	17,300	20,220	109	0	90	146
GDP (billions of $2010)	1,707	2,624	11	7	29	37
Labour Productivity (Output per Worker) ($2010)	98,661	129,781	-188	312	820	861
Implied Compound Annual Growth Rates (CAGR) (per cent), 2011-2031						
Employment	-	0.78	0.81	0.78	0.81	0.82
GDP	-	2.17	2.19	2.19	2.23	2.24
Labour Productivity	-	1.38	1.37	1.39	1.41	1.41
2011-2031 CAGR Relative to Baseline (percentage points increase)						
Employment	-	0.0000	0.0271	0.0000	0.0224	0.0361
GDP	-	0.0000	0.0200	0.0123	0.0549	0.0704
Labour Productivity	-	0.0000	-0.0074	0.0122	0.0320	0.0335

Source: Author's calculations based on the 2011 National Household Survey Public Use Microdata File and Aboriginal population projections from Population Projections by Aboriginal Identity in Canada, 2006 to 2031, Statistics Canada, Demography Division.

quantified the potential value of these benefits for both the Aboriginal population and Canada as a whole and confirmed that they could be substantial. In particular, we have estimated that eliminating the Aboriginal educational attainment gap in Canada by 2031 could raise the growth rate of labour productivity by 0.03 percentage points over the 2011-2031 period and the growth rate of employment by 0.02 percentage points. These increases in labour productivity and employment would result in a cumulative increase in GDP of $261 billion (2010 dollars) between 2011 and 2031.

Given the very high potential benefits of improving Aboriginal education compared to current Aboriginal education spending levels, further investments in Aboriginal education are warranted.[27] However, we have not considered how the gap could actually be closed in practice or how much this may cost. Further research is necessary to identify the most cost-effective approaches to realizing the benefits associated with improved Aboriginal education. Drummond and Rosenbluth (2013) note that many First Nations schools remain underfunded when compared with similar non-Aboriginal schools in terms of costs and needs. It seems reasonable to expect that Aboriginal students will require at least the same level of funding as comparable non-Aboriginal students if we are to expect similar outcomes. Utilizing existing funds in the most efficient way and addressing other social factors which may ultimately be contributing to the educational attainment gap will undoubtedly be important components of the solution. A better understanding of the causal relationships between social conditions, Aboriginal education, and labour market outcomes is needed.

27 Aboriginal Affairs and Northern Development Canada spent $1.55 billion on First Nations elementary and secondary education from 2011-12, plus $200 million on education infrastructure on-reserve (Drummond and Rosenbluth, 2013).

While we believe that the estimates presented in this report represent an improvement over the previous estimates produced by the CSLS, better estimates are possible. The limited sample sizes in the NHS Public Use Microdata Files are somewhat problematic for accurately estimating the economic benefits for smaller subsets of the population. Using a data source with a larger sample would be preferable if possible.

While generating our estimates, we found that controlling for demographic and geographic features had a significant impact (Calver, 2015). However, we were not able to control for one very important characteristic which differs between the Aboriginal and non-Aboriginal populations: urban/rural status.

The methodology utilized to project educational attainment in 2031 is admittedly quite crude. We recommend that future estimates should adopt a cohort based projection approach and should use trends within each age-sex-province category rather than applying the national trends universally.

Lastly, the scenarios we have considered in which the gaps have closed by 2031 have been very unrealistic. In particular, we assume that closure will happen across the board for all age groups, even for those who are already above the age of 30. This is extremely unlikely to occur in practice. More nuanced scenarios can be developed.

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Why Isn't Productivity More Popular? A Bargaining Power Approach to the Pay/ Productivity Linkage in Canada

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ABSTRACT

Canadian real labour income has increasingly lagged behind productivity growth. This article employs a bargaining power approach to wage determination to explore the hypothesis that some public polices intended to promote productivity growth may have contributed to the erosion of worker bargaining power, thereby reducing workers' capacity to benefit from productivity growth. We present an econometric analysis of several policies that supports this hypothesis.

PROMINENT CANADIANS (Carney 2010; Mulroney 2011; Dodge 2005), research organizations, and the media repeatedly endorse the virtues of productivity. The benefits of productivity growth seem self-evident: rising productivity generates more output (GDP), and a higher standard of living (typically defined as GDP per capita). There is even a "surprisingly broad consensus" (Drummond and Bentley, 2010) among economists on a policy agenda to enhance productivity growth. The "productivity agenda" typically includes calls for lower taxation of capital and marginal tax rates on individuals, deregulation, Employment Insurance (EI) reform, trade and investment agreements, and many other policy initiatives intended to maintain low and stable inflation, reduce government deficits and debt, and increase labour market flexibility (Drummond, 2006).

Yet despite the consensus in public policy circles concerning the desirability of enhancing Canadian productivity growth, the productivity agenda does not appear to be widely popular. Pollster David Herle indicates that "most people do not see how…the productivity agenda in general will have a positive impact on their lives"(Herle, 2007). Productivity may even be becoming less popular over time: Environic's quarterly Focus Canada poll

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of 2,000 Canadians found that the number of Canadians who agreed that increasing productivity is "very important" decreased by 18.4 percentage points between 1985 and 2005.[2] Don Drummond (2011:5) claims that public aversion to the concept of productivity is so intense that government officials dare not refer to it by name:

> ... Canadian governments react to the public's misunderstanding, even fear of productivity by borrowing a concept from Harry Potter. Just as Lord Voldemort must be referred to as "He-Who-Must-Not-Be-Named" or the "Dark Lord" so must productivity be globally replaced by 'innovation' or "competitiveness."

What accounts for the lack of popularity of the productivity agenda? Often advocates of the productivity agenda blame widespread misunderstandings of the concept of productivity, suggesting that the public interprets calls to increase productivity growth as a "code" for longer working hours and intensified work (Drummond and Bentley, 2010) or the prelude to job loss in particular industries. Whatever the merits of these explanations, this article takes a different approach: it employs a distributional perspective to understand the unpopularity of the productivity agenda.

Certainly productivity growth means that the economy generates more output from its natural resources, labour, and capital. But this begs the question of who will benefit from this increased productivity. Proponents of the productivity agenda typically argue that productivity growth will be broadly beneficial thanks to the wide distribution of the gains from productivity via the wage mechanism. The presumption that real wages will grow as productivity increases is not only ubiquitous in introductory economics textbooks, it has an immense influence on public policy. For example, education and training programs are premised on the expectation that investments in human capital will enhance labour income (Rennison and Turcotte, 2004). The productivity-real wage linkage is not always explicitly stated when governments promote policies consistent with the productivity agenda (indeed, to the extent that the term productivity is unpopular, it would likely be avoided in public pronouncements). But arguably the pay/productivity linkage is invoked via the frequent rhetoric emphasis on "good" jobs and "prosperity" that are said to accompany policies consistent with the productivity agenda.[3]

Yet a strong pay/productivity linkage is not borne out by empirical examination. While in the decades prior to the 1980s, the pay/productivity linkage was relatively robust, wages have not grown in tandem with productivity growth in Canada (and elsewhere) recently. The International Labour Organization estimates that labour productivity has increased more than twice as much as average wages in developed countries as a whole between 1999 and 2011 (International Labour Organization, 2013). This trend has been echoed in Canada.[4] A recent report of the Parliamentary Budget Office (Bartlett and Tapp, 2012:14) concluded that this divergance of remuneration and productivity growth has become a persistent attribute of Canadian labour markets:

2 As calculated by comparing Environics Focus Canada polls from 1985 and 2005.

3 A recent example of this rhetoric was included in the materials promoting the Canada-European Union Comprehensive Economic and Trade Agreement "Across Canada, businesses, workers and their families will enjoy many new opportunities resulting from free trade with the European Union, translating into good jobs, economic growth, and greater long-term prosperity" (Government of Canada, 2013).

4 See Sharpe, Arsenault and Harrison (2008b).

> Labour productivity growth has outpaced the growth in the real total compensation rate, on average, over the past three decades. This is particularly true since the mid-1990s, suggesting that productivity gains over this time have not led to equivalent increases in compensation.

It seems reasonable that public enthusiasm for measures intended to enhance productivity growth would wane to the extent that the benefits of productivity are not translated into paycheques. Moreover, we make the case that the delinkage of real wages and productivity growth may be attributed – in part – to the very policies that were introduced to encourage productivity growth. We present a bargaining power approach to wage determination to consider conditions which may impact workers' capacity to secure the benefits of rising productivity growth in their paycheques. We argue that several of the public polices implemented in the name of enhancing productivity growth have reduced workers' bargaining power, thereby undermining workers' capacity to benefit from productivity growth. If the policies intended to boost productivity also contribute to the diminished ability of workers to secure the benefits from growing productivity, this situation would be an important consideration in understanding the lack of popularity of the productivity agenda.

We present an econometric analysis to explore how the pro-productivity policy environment may contribute to the delinking of real wages and productivity growth. This econometric analysis focuses on certain attributes of EI reform and the North American Free Trade Agreement, which are policies explicitly linked to the productivity agenda. In addition, we examine union membership, minimum wage regulations, and unemployment rates. While these variables are not the direct outcome of particular policy initiatives explicitly introduced as part of the productivity agenda, they are impacted by a range of policy initiatives prompted in part by the anti-inflation, deregulatory, and labour market flexibility themes that are prominent in it.

This article is divided into three sections. Section one argues that there is no necessary link between real wages and productivity growth, and that the relative bargaining power of employers and employees will determine how the fruits of productivity growth are shared. Section two conducts an empirical examination of the linkage between pay and productivity in the Canadian context and discusses some conceptual, measurement, and data issues that have muddied the assessment of this linkage. It concludes that between 1961 and the late 1970s, the real wage/productivity linkage was relatively tight, but thereafter productivity growth generally outpaced compensation. Section three argues that some of the public policies associated with the productivity agenda have played a role in undermining the bargaining power of workers in this later time period. We present an econometric analysis to demonstrate that these policies have been associated with a widening pay/productivity gap.

Productivity and Real Wage Growth: A Bargaining Power Approach

"Ask any economist and he or she will tell you that faster productivity growth leads to higher real wages..." (Walsh, 2004). While the real wage/productivity linkage is often asserted as an economic truism, there is no necessity that real wages must rise in tandem with productivity. As we discuss below, for several decades prior to the late 1970s, a close empirical relationship existed between the growth of productivity and real wages in Canada and elsewhere, but it no longer holds. Nor does economic theory dictate that real wages must follow productivity growth. Economists trained in neoclassical economic theory are well acquainted with some widely-used special cases, such as the Cobb-Douglas production function, which is constructed according to several highly restrictive assumptions so that it is a mathematical necessity that wages and productivity grow in tandem.[5] The frequent reference to the real wage/productivity connection may be the result of the fact that many of the most influential conclusions of neoclassical economic theory proceed from situations in which the real wage/productivity link does hold.[6] But except in special circumstances (such as the Cobb-Douglas case), rising productivity does not necessarily produce a proportional increase in real wages.

In practice, while rising productivity creates resources which may be distributed as rising real wages, they don't have to be. We view the distribution of the gains from productivity growth as a question of the relative bargaining power of employees and employers. Worker bargaining power refers to the capacity of workers to compel their employers to accept contractual terms that are favourable to them. In an environment of relatively strong worker bargaining power, employees are in a better position to secure increases in their compensation. Consequently, while labour productivity improvements do increase the resources to be shared between employers and employees, it is the relative bargaining power of each group that ultimately determine how much (if any) of the fruits of productivity growth are allocated to increased wages.

What determines the relative bargaining power of workers and their employers? As Max Weber (1947:152) helpfully states, "[p]ower is the probability that one actor within a social relationship will be in a position to carry out his own will, despite resistance, regardless of the basis on which this probability rests". Certainly bargaining power is shaped by the typical demand and supply considerations familiar to any labour economist. But in principle, anything within the firm, industry, labour market, larger society or international sphere could affect the relative bargaining power of employers and employees. To be sure, any number of considerations, such as technological change and various attributes of globalization, are relevant to a bargaining power analysis. However, this article focuses on factors that are directly or indirectly linked to the productivity agenda in order to examine the possibility of a link between policies undertaken to enhance productivity and worker bargaining power.

Worker or employer bargaining power is enhanced to the extent that either party can deliver a credible threat of injury to the opposing party. For example, employers may threaten to move production overseas to secure wage concessions. Relative bargaining power will be affected by public policies that either a) enhance the ability of either employers or employees to make threats, and/or b) affect the credibility of such threats. Thus if any public policies advocated as part of the productivity agenda can be

5 Cobb-Douglas assumptions are constructed so that marginal and average productivity are proportional and vary together if we assume a stable labour share. Moreover, capital and labour must be freely substitutable for one another instead of there being, say, a relatively fixed amount of capital per worker (e.g. one car per cab driver). Also, workers and units of capital are aggregated in a way that makes them undifferentiated (all workers are alike).

6 For example, the neoclassical argument on behalf of the Pareto-optimal allocation of resources is predicated on the situation in which real wages are tightly linked with labour productivity. This pay/productivity linkage is also central to the standard of distributive justice employed in neoclassical theory, namely that remuneration is meritocratically determined by workers' contribution to production.

shown to either increase the capacity of employers to make credible threats, or reduce the capacity of workers to make credible threats, then these policies contribute to undermining worker capacity to secure the benefits of increased productivity growth in the form of rising real wages.

Bargaining power analysis also concerns the so-called "fallback" position. Each party to a negotiation must consider the situation they will likely face if negotiations are resolved in a manner that is unfavourable to them. For example, employees must consider the situation they face if negotiations were to lead to the termination of their employment (or some other undesirable outcome). Workers assess many considerations in determining their fallback position in the event of job loss, including their savings or other sources of income, the likelihood of securing another job and so on. Worker fallback positions are influenced by public policies, including those policies that provide income during periods of unemployment or other forms of support to both the unemployed and people with low incomes. To the extent that policies associated with the productivity agenda undermine the fallback positions of workers, these policies would contribute to a situation in which workers are less likely to translate productivity growth into rising paycheques.

An Overview of the Canadian Data on Pay and Productivity

Since there is no theoretical necessity of a strong wage/productivity linkage, we must examine the empirical record to ascertain the degree to which real wages in Canada have risen in tandem with productivity growth. This section presents evidence suggesting that there have been two distinct historical epochs since the 1960s regarding the wage/productivity link. Between 1961 and the late 1970s, the real wage/productivity linkage was relatively tight, but thereafter productivity growth generally outpaced increases in compensation.

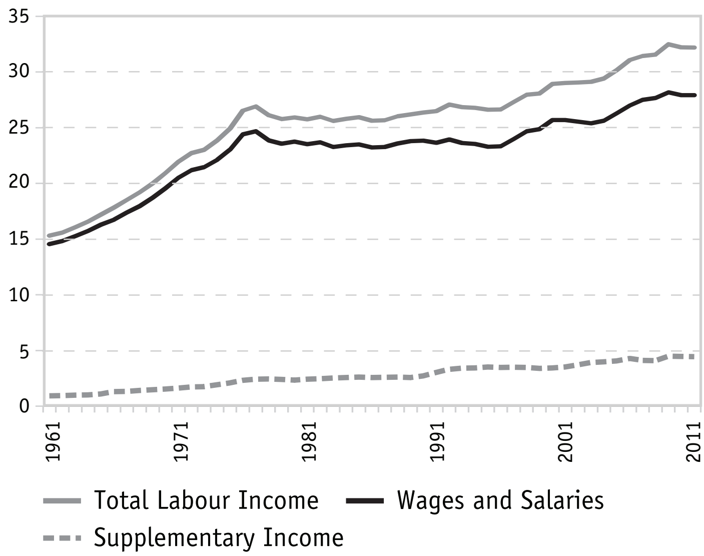
To address this issue in the Canadian context, we work with Statistics Canada's labour income statistics. Labour income statistics have three helpful attributes. First, because this data set extends between 1961 and 2011, it permits the examination of trends over time. Second, this definition of labour income captures over 89-90 per cent of all workers' income throughout the period and about 95 per cent of that income from the mid-1970s onward. Third, Statistics Canada's category "labour income" excludes the self-employed. There is not a clear distinction between wages, profits, and other forms of income for the self-employed. Consequently, estimating the wage-implicit component of self-employed income poses problems ranging from reporting issues to measurement difficulties inherent in the attempt to distinguish income derived from labour versus income derived from profits or other avenues.[7] The exclusion of the self-employed does not dramatically alter the overall conclusions derived below, since the trajectory of the increase in the imputed real wages of the self-employed closely corresponds to that of other workers.

The empirical investigation of the productivity/real wage relationship must grapple with the definition of what constitutes wages.[8] In recent decades, workers increasingly receive non-wage compensation in the form of pensions, health insurance, and a variety of other employer-paid benefits in addition to their paid wages. Feld-

7 Efforts to impute labour income for the self-employed are often based on the questionable assumption that the self-employed earn the same, on average, as comparable paid employees. Freeman (2011) discusses the difficulties of estimating labour income from self-employment.

8 We use the term "wages" and "salaries" interchangeably.

Chart 1
Components of Real Hourly Labour Income based on the CPI, 1961-2011
(expressed in 2011 dollars)



Sources: Statistics Canada, CANSIM database, Tables 326-0021, 382-0001, 382-0006, 383-0003.

stein (2008) followed others (Bosworth *et al.*, 1994, Anderson 2007) in arguing that a narrow focus on wages understates the full extent of employee remuneration, and thus contributes to understating the extent to which workers benefit from productivity growth. Feldstein and others insist that the relevant comparison is between productivity growth and all forms of employee compensation, which includes both paid wages and other fringe benefits and noncash compensation made by employers.

Chart 1 presents real total hourly labour income between 1961 and 2011, including both wages and salaries[9] and "supplementary income."[10] Supplementary income consists of a wide variety of employer payroll contributions including pension and health care benefits.[11] Chart 1 has accounted for inflation using the Consumer Price Index (CPI), as the CPI is the best indicator of the changes in the prices of goods and services purchased by workers.

Chart 1 illustrates that supplementary income is a rising proportion of total labour income over time. It also suggests that real labour income grew rapidly prior to the mid-1970s, but stagnated until the late 1990s when it resumed an upward trend (although at a much slower pace than was the case prior to the 1970s). While this comprehensive approach to employee remuneration undoubtedly captures some payments made by employers that are close substitutes for wages, it is debatable whether all of the items included in supplementary income should be viewed as non-wage compensation, as Leckie and Caron (1991) have acknowledged in a Statistics Canada publication.[12] There are two rea-

9 Statistic Canada defines "wages and salaries" as regular earnings, special payments, stock options and bonus payments.

10 In all charts, the most recent source of data is used for any given year. For example, labour income is obtained from Cansim Table 382-0001 for 1961-1996 and Table 382-0006 for 1997-2011, even though the data in table 382-0001 goes to 2001. This methodological choice does not have a notable impact on the results.

11 Supplementary income as defined by Statistics Canada includes pensions, employment insurance, Canada/Quebec pension plan, worker's compensation, welfare –such as employers contributions to health insurance—and retiring allowances, or "severance pay, including payments for unused sick leave credits and other amounts received upon termination of employment.

12 "Supplementary labour income (SLI) is neither a true benefit nor a true income in the sense of money directly received by employees. SLI represents the contributions to public and private health and welfare plans made by employers on behalf, and for the future benefit, of their employees. While employer contributions may well be the most practicable measure of these benefits, the use of this indicator of SLI is at times misleading. Changes in employer contributions and in employee benefits do not necessarily move in tandem. For instance, changes in financing arrangements or financial conditions may alter employer premiums without producing a corresponding effect on benefit levels. Indeed, where public benefit plans receive a continuing subsidy out of general taxation revenues, the use of employer premiums alone will chronically underestimate the value of the benefits provided" (Leckie and Caron, 1991).

sons that the inclusion of all items in supplementary income may lead to an overstatement of worker remuneration: one concern is that some of these payments function in a manner analogous to taxation,[13] and the second concern focuses on the declining accessibility of the programs funded by some of these payments.

Some forms of supplementary income might arguably be viewed as taxation such as employer contributions to employment insurance (EI) and workers' compensation. These contributions amounted to 21 per cent of supplementary labour income in 2005 (Sharpe, Arsenault and Harrison, 2008, Appendix Table 5). Unlike private retirement or health insurance benefits, employment insurance and workers' compensation are not matters that are internal to the employment contract. These government-mandated payments cover benefits extended via publically-administered programs which could have been designed to be funded through general taxation. Since surplus employment insurance premium revenues have been allocated to government purposes other than funding employment insurance (witness the use of EI funds to reduce the federal deficit in the 1990s), employment insurance premiums might well be regarded as more analogous to taxation than, say, private employer pension contributions.

In reference to the motivations for this article regarding public perception about the benefits of productivity growth, we think it unlikely that the inclusion of payments to fund government social programs is viewed as interchangeable with other types of non-cash compensation as workers assess their total labour income over time. For example, EI benefits paid have become less generous[14] and more difficult to obtain in recent decades. As the probability of receiving these benefits has declined, it seems likely that workers will be less willing to assess these payments as a meaningful portion of their compensation package. It should also be noted that an important component of the labour force is engaged in jobs that offer little or none of the pension, health care or other benefits contained within supplementary income.

Despite these concerns, we have elected to include all forms of supplementary income as part of total worker remuneration, thus adopting the most generous possible assessment of employee pay. This operates to the advantage of those arguing on behalf of a tight linkage between pay and productivity growth.

Another empirical concern raised by Feldstein (2008) and others focuses on the methodology used to adjust nominal dollar amounts for inflation. Chart 1 uses the CPI, which assesses the inflation of all consumer goods purchased by households (including imported consumer goods). Feldstein insists on the use of the GDP deflator, which assesses the inflation of all new domestically produced final goods and services. His insistence on the use of the GDP deflator derives from the neoclassical argument that the nominal wage is equal to the marginal revenue product of labour, which is the marginal product of labour multiplied by the price of the firm's output. Since firms consider the likely price of their output as they bargain over wages, the deflator representing changes in the product price (the GDP deflator) should be used to compare real wages and productivity growth (Feldstein, 2008). There are objections to this approach. For example, Mishel (2012) argues

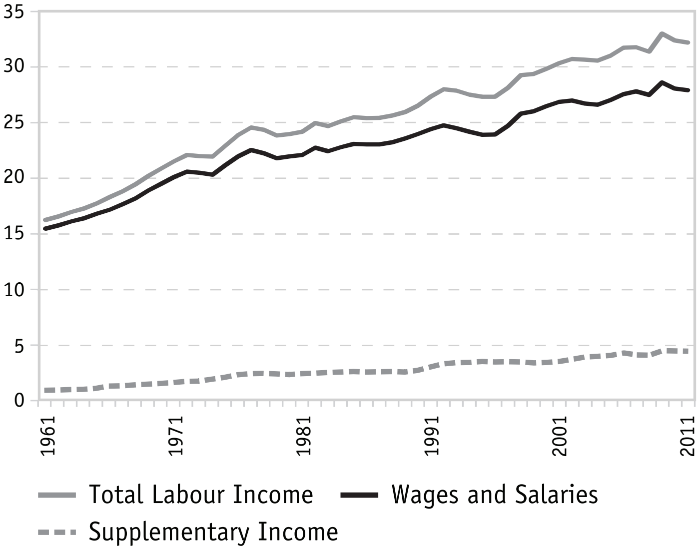
13 The International Labour Organization acknowledges that total compensation may be overstated by including taxation-like payments, and therefore the ILO excludes employer social security contributions in its concept of "total cash remuneration" (International Labour Organization, 1998).

14 In the last three decades, the average percentage of earnings replaced by EI benefits peaked in the early 1990s at slightly over 44 per cent, and have since dropped to around 40 per cent (Osberg and Sharpe, 2011).

Chart 2

Components of Real Hourly Labour Income based on the GDP Deflator, 1961-2011

(expressed in 2011 dollars)

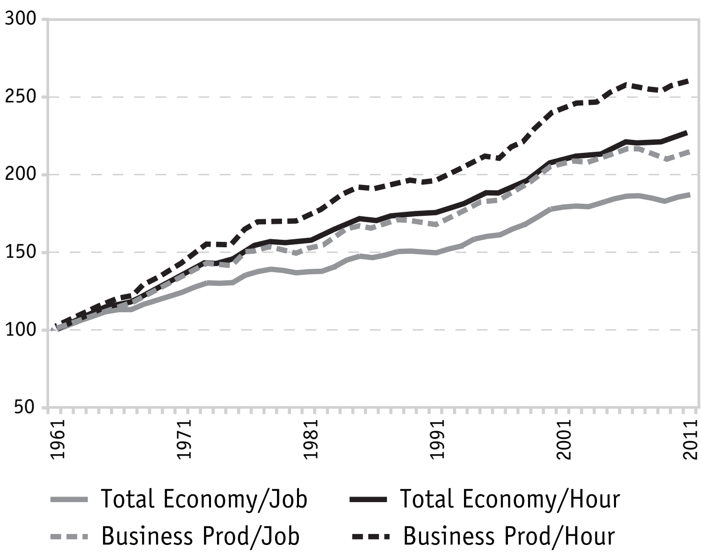


Sources: Statistics Canada, CANSIM database, Tables 380-0056, 382-0001, 382-0006, 383-0003.

Chart 3

Labour Productivity in the Total Economy and the Business Sector, 1961-2011

(1961=100)



Sources: Author's calculations and data from the Centre for the Study of Living Standards.

that workers are focused on changes in what they can buy over time when they assess how much they have benefited from productivity growth.[15] Nevertheless, Chart 2 recalculates the information from Chart 1 using the GDP deflator. The resulting chart depicts a more steady rising of real labour income over time.

Our analysis requires an assessment of productivity with which to compare the progress of total labour income. Chart 3 presents several measures which confirm the growth in labour productivity over the relevant time period.

We use the productivity measure expressed as total economy per hour for the subsequent analysis as opposed to the business sector. The justification for this choice of productivity measure is threefold. First, in terms of the denominator, we require a productivity measure expressed in hourly terms because total labour income is expressed at an hourly rate. Second, in terms of the numerator, we select a measure related to the total economy since total labour income encompasses the earnings of all workers rather than business sector workers alone. Note that the selection of the GDP numerator operates to the advantage of those arguing on behalf of the pay/productivity linkage, given that the productivity measures related to the business sector rise faster than those related to GDP. Third, the choice of a measure of productivity growth expressed in terms of hours has the added virtue that it accounts for the change in the annual number of hours per worker, thus better reflecting the true relationship between labour productivity and actual labour input.

Chart 4 presents the comparison between total real hourly labour income and real hourly labour income grown at the rate of productivity growth between 1961 and 2011.

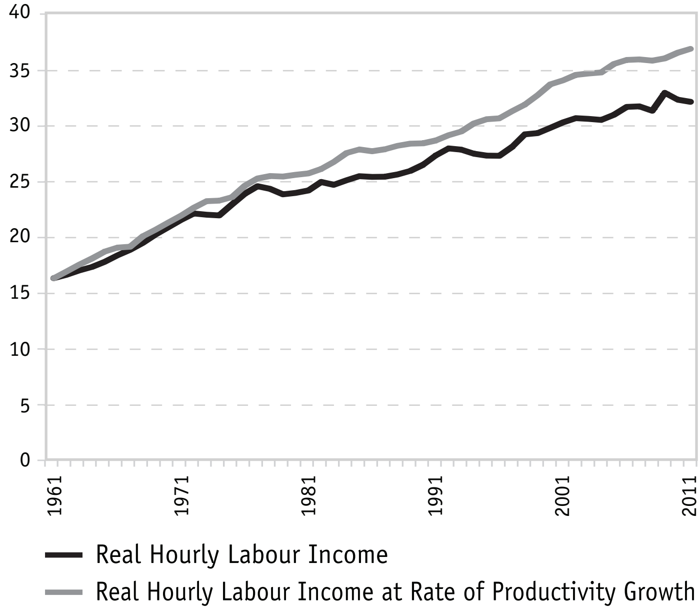
15 Mishel's analysis accounts for the distinction between these methods of accounting for inflation by including a terms of trade measure (Mishel, 2012).

The "real hourly labour income" line represents the rate at which total hourly real labour income grew, while the "labour income at the rate of productivity growth" line represents the rate at which total hourly real labour income would have grown had it identically matched productivity growth (defined as total economy output per hour). Productivity and pay measures are equated at the beginning of the time period under examination as this facilitates the examination of the relative progress of the growth of productivity and pay over time.[16] Some analysts construct the pay and productivity lines to converge in some midpoint in the era under investigation (Rao, 2011). However, this approach tends to understate the visual appearance of any divergence between the two lines.

Chart 4 depicts two distinct historical periods. Between 1961 and the late 1970s, total labour income was rather tightly linked with productivity growth, but by the early 1980s, they began to diverge. Productivity growth did outpace compensation growth during this last period, except for some years in the early 1990s and late 2000s. But even these "catch-up" periods, when compensation growth exceeded productivity growth, were not enough to reverse the overall trend. By 2011, average labour income per hour—expressed in 2011 dollars—was $32.20, while it would have been $36.97 had it followed average productivity growth. If pay had followed productivity, workers would have earned an additional 14.8 per cent per hour; instead the $4.77 differential went to employers.

While Chart 4 illustrates the increasing disconnect of real labour income and productivity growth across employees in general, there are indications that some workers fared better than

Chart 4
Comparison of Actual Hourly Labour Income and Hourly Labour Income at Rate of Productivity Growth, 1961-2011
($2011, GDP deflator)



Sources: Statistics Canada, CANSIM database, Tables 380-0056, 382-0001, 382-0006, 383-0003, 383-0009 and the Centre for the Study of Living Standards.

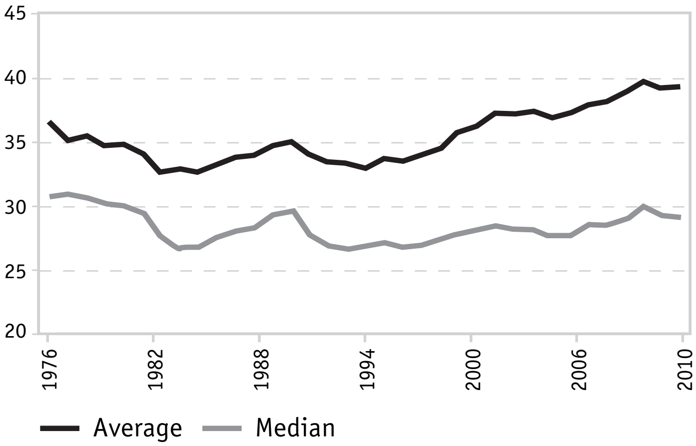
others. To investigate this possibility, we used Statistics Canada's data on annual earnings, which differ from labour income, in order to compare average and median earnings. Statistics Canada defines earnings as income from paid employment, wages, salaries, commissions and self-employment, so it excludes supplementary income, but includes all other income categories from labour income and self-employment. As Chart 5 illustrates, average earnings are consistently higher than median earnings because higher income workers' earnings are far enough above the median to pull up the average. This difference has been increasing in recent decades. Since the early 1990s, average earnings have

16 By equating productivity and labour income at the onset of the time period, this equation focuses attention on any divergence between the growth of labour income and productivity growth. It should not be interpreted as evidence that neoclassical conditions concerning the equation of labour income and the marginal revenue product of labour held at the beginning of the time period.

Chart 5

Real Average and Median Annual Earnings, 1976-2010

(Thousands of 2010 dollars, CPI adjusted)



Sources: Statistics Canada, CANSIM database, Table 202-0101.

increased steadily such that the real average earnings of workers in 2010 exceeded their level in 1976 by $2,800. However, real median earnings have lost ground. The median worker earned $700 less in 2010 than she did in 1976, in 2010 dollars. In 1976, average earnings were 119 per cent of median earnings, while by 2010 average earnings were 134 per cent of median earnings.

This increasing divergence between average and median earnings since the early 1990s suggests a situation in which higher income workers have been much more successful than lower income workers in translating productivity gains into increased real earnings.[17]

The concern that lower income workers are much less capable of receiving the benefits of productivity growth in their own paycheques is reinforced by Table 1, which shows real wage growth (exclusive of supplementary income) by occupation from 1997 to 2010, with occupations ranked by the average hourly wage rate at the beginning of the period.[18] Employees in all occupations saw average annual real wage growth of 0.89 per cent, which falls far short of average productivity growth of 1.20 per cent. However, the experience of the well-paid occupational categories differs starkly from the lower paid occupational categories. The only occupational categories for which workers experienced a wage growth faster than average productivity growth, such as "senior management occupations," are in the upper portion of the table, with an above-average wage rate at the beginning of the period. Of the occupational categories with a below-average wage rate in 1997, only the remuneration linked to "occupations unique to primary industries" grew at a pace close to that of productivity. Incomes in only one other sub-category – chefs, cooks and other occupations in the food industry – increased faster than average.

Bargaining Power and Productivity Policies

In an effort to explain the increasingly weak pay/productivity link in Canada, this section examines the possibility that policies associated with the productivity agenda erode workers' bargaining power and thereby undermine their capacity to secure the benefits of productivity growth in their paycheques. This analysis proceeds by highlighting the two dimensions of bargaining power – threat effects and fallback positions – that were introduced above. We discuss several policies associated with the productivity agenda that may have either influenced the relative capacity of workers and employers to issue credible threats, or their fallback positions. The section concludes with an econometric

17 There is evidence suggesting that much of the income growth has occurred at the very top of the distribution, particularly the top 1 per cent of earners, who are concentrated in finance, management, and the professions (Fortin *et al.*, 2012)

18 All subcategories of occupations are included in this table. In instances where no subcategories were available, broad categories were used.

Table 1
Real Hourly Wage Growth by Selected Occupations, 1997-2010

National Occupational Classification for Statistics (NOC-S)	Annual Hourly Real Wage 1997 ($2011)	Annual Real Wage Compound Growth (hourly) 1997-2010
Senior management occupations	*35.72*	*1.61*
Teachers and professors	30.17	0.44
Professional occupations in health, nurse supervisors and registered nurses	*27.60*	*1.40*
Senior management occupations	*27.27*	*1.77*
Natural and applied sciences and related occupations	27.05	1.09
Professional occupations in business and finance	*25.98*	*1.28*
Contractors and supervisors in trades and transportation	25.39	0.87
Occupations in social science, government service and religion	22.78	1.02
Other trades occupations	22.19	0.71
Occupation in protective services	22.08	0.63
Wholesale, technical, insurance, real estate sales specialists, and retail, wholesale and grain buyers	21.43	0.72
Construction trades	21.2	0.48
Occupations in art, culture, recreation and sport	20.48	0.76
Total employees, all occupations	20.09	0.89
Technical, assisting and related occupations in health	20.05	0.56
Financial, secretarial and administrative occupations	19.90	0.64
Transport and equipment operators	18.92	0.63
Machine operators and assemblers in manufacturing, including supervisors	18.79	0.47
Clerical occupations, including supervisors	17.32	0.55
Trades helpers, construction, and transportation labourers and related occupations	17.08	0.35
Occupations unique to primary industry	16.65	1.19
Labourers in processing, manufacturing and utilities	16.03	-0.29
Childcare and home support workers	15.3	0.3
Sales and service occupations not elsewhere classified, including occupations in travel and accomodation	12.91	0.42
Retail salespersons, sales clerks, cashiers, including retail trade supervisors	12.06	0.64
Chefs and cooks, and occupations in food and beverage service, including supervisors	11.64	0.96

Note: Italicized catagories exceed compound average annual productivity growth of 1.20.

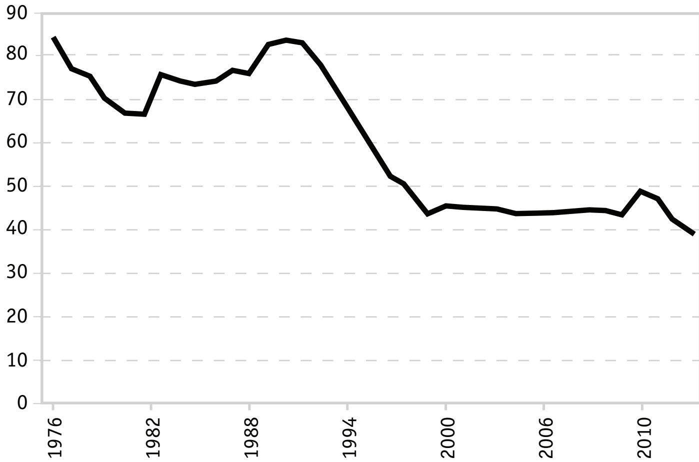
Sources: Labour Force Survey, Statistics Canada, CANSIM database, Tables 282-0070 and 326-0021.

analysis of several prominent pro-productivity policies to explore the relationship between these public policies and the gap between pay and productivity.

Policies related to the productivity agenda have several elements that shape threat effects. For example, we would expect international agreements such as the North American Free Trade Agreement (NAFTA) to diminish worker bargaining power to the extent that they facilitate the relocation of production abroad. Trade agreements, such as NAFTA and the 1988 Canada-US Free Trade Agreement, have been introduced as a means to "raise Canada's productivity and …thereby provide permanently higher real incomes for Canadians" (Department of Finance, 1988:27). Another theme in the productivity agenda has been the promotion of "labour market flexibility".[19] The pursuit of labour

19 Karabegovic, Gabler and Veldhuis (2012) provide a good overview of prominent policies associated with labour market flexibility.

Chart 6
EI Coverage Ratio, 1976-2012
(per cent of unemployed receiving regular EI benefits)



Sources: Statistics Canada, CANSIM database, Tables 276-0001, 282-0048.

market flexibility has influenced many diverse public policies, which in turn have affected the capacity of workers and employers to issue credible threats. These include legislative, judicial and procedural developments that constrain the capacity of unions to organize, undermine job security, and inhibit unions and workers from engaging in various forms of militancy.

The employment insurance system has been extensively restructured in recent decades, often with the explicit objective of enhancing labour productivity and creating "good jobs" (Human Resources Development Canada, 1994). Various reforms have resulted in an EI system that covers fewer unemployed workers (Chart 6), and that is less generous in the income it replaces for those that do qualify. Both of these changes to the EI system would be expected to make workers' fallback positions more precarious, thus contributing to declining worker bargaining power.

In considering their fallback positions, workers must assess their alternative employment prospects. Thus, the overall unemployment rate will factor into worker assessments of the likelihood of obtaining alternative employment and the wages associated with that employment. Anti-inflationary monetary policies which are prominent in the productivity agenda have tended to increase the unemployment rate (Fortin, 2001). Another consideration in workers' assessment of their fallback position is the level of remuneration they are likely to secure if they do find alternative employment. Since workers' worst case scenario is that they will be paid minimum wage, statutory minimum wages influence workers' fallback positions. Moreover, wages slightly above the statutory minimum wage rate may be influenced by the minimum wage level. Real minimum wages in Canada dropped through the first half of the 1980s, and have only barely surpassed their 1980 value in the late 2000s in most provinces. While the failure of the statutory minimum wage to rise in real terms often reflects policy inaction, demands for minimum wage increases are often condemned by advocates of labour market flexibility (Elgrably, 2006).

In short, a variety of public policies associated directly or indirectly with the productivity agenda may affect relative bargaining power to the detriment of employees by constraining their capacity to issue credible threats, making their fallback positions less attractive, or by enhancing their employers' recourse to threats and/or fallback position. As an illustration of the way public policies could have influenced the bargaining power of workers and their ability to capture the fruits of productivity growth over the last decades, we identified some quantifiable variables that may be expected to have an influence on bargaining power and estimated their impact on the productivity-income gap. Four of the variables we examined are directly related to public policies: the rate of coverage of EI, the relative generosity of EI benefits, the rate of growth of real minimum wage, and the North-American Free Trade Agreement. Two additional variables which could be expected to have an important impact on workers' bargaining power are the unemployment rate and the rate of union membership. These are included in the analysis because the anti-inflation and labour market flexibility aspects of the productivity agenda have encouraged various government actions that affect these variables.

The equation estimated is the following:

$$Gap_{i,t} = \beta_0 + \beta_2 Gap_{i,t-1} + \beta_3 Gap_{i,t-2} + \beta_4 U_{i,t}$$
$$\beta_5 EICov_{i,t} + \beta_6 IncRep_{i,t} + \beta_7 MinW_{i,t} + \beta_8 UMem_{i,t}$$
$$\beta_9 Nafta_{i,t} + \sum_{j=1985}^{j=2010} \alpha_j T_j$$

Where the subscript *i* identifies the province, *t* is the time period, *Gap* is the difference between the growth rate of productivity and the growth rate of labour income, *U* is the rate of unemployment, *EIcov* is the rate of coverage of employment insurance, *IncRep* is the average proportion of earnings replaced by EI benefits, *MinW* is the rate of growth of minimum wage, *UMem* is the rate of union membership, *Nafta* is a dummy variable taking the value of 1 after the start of the North American Free Trade Agreement (from 1994 onward), and *T* is a series of time dummies, using 1984 as the base year.[20]

We estimated this equation for the period spanning from 1981 to 2010, using annual data for every province, via an Arellano-Bover/Blundell-Bond linear dynamic panel estimation.[21] We estimated two regressions, the second one without the rate of coverage of employment insurance because of the very low statistical significance of the variable's estimated coefficient in the first regression. Estimation results are laid out in Table 2.

The coefficients on the lags of Gap are both negative and statistically significant in both regressions, which suggests that an increase in the income-productivity gap in one year does not lead to an explosive process of increases in subsequent years. While these increases do add up, as we have shown above, there seems to be a tendency for some catching up immediately after the gap increases.

As can be expected, the rate of unemployment has a positive and strongly statistically significant effect on the gap. This is consistent with the proposition that higher unemployment rates reduce worker bargaining power. Employment insurance is an important component of workers' fallback and expectedly, the higher the proportion of income covered by EI benefits, the lower the productivity-pay gap for that year. The coefficient of the rate of coverage of EI is not significant in the first regression, which is surprising at first blush. However, given the way the program was reformed by the Liberal government in the 1990s, there is a major drop in coverage that is concentrated over those years while the rate is otherwise relatively stable, which could make its yearly effect difficult to measure.

The coefficient of the rate of union membership is marginally statistically insignificant

20 Data sources for the econometric analysis include Cansim Tables 382-0001, 382-0006, 282-0028, 384-0038 for the gap; Human Resources and Skills Development Canada for the minimum wage; Cansim Tables 282-0048, 276-0001 for the EI coverage rate; Osberg, Lars and Andrew Sharpe (2011, Table 19) for the EI replacement ratio; Cansim Table 282-0086 for the unemployment rate; and Cansim Tables 279-0025, 282-0220 for union membership.

21 We employ Arellano-Bover/Blundell-Bond linear dynamic panel estimation in order to adjust for the endogeneity between the lagged dependent variable and the province-specific effects. To do so, the model is transformed into first differences and instrumental variables are computed from lagged dependent variables and lagged differences, in a generalized method of moments approach.

Table 2
Econometric Results

Dependent variable: Gap_t	(1)	(2)
Gap_{t-1}	-0.309***	-0.307***
	(0.036)	(0.041)
Gap_{t-2}	-0.441***	-0.438***
	(0.063)	(0.071)
U_t	0.0051***	0.0053***
	(0.0011)	(0.0012)
$EICov_t$	0.000075	
	(0.00045)	
$IncRep_t$	-0.0022*	-0.0022*
	(0.0013)	(0.0013)
$MinW_t$	-0.089*	-0.087*
	(0.046)	(0.046)
$UMem_t$	-0.0018	-0.0017*
	(0.0011)	(0.0009)
$Nafta_{t-1}$	0.053*	0.053*
	(0.029)	(0.03)
Number of observations	270	270
Years covered	1981-2010	1981-2010

Estimates are obtained using an Arellano-Bover/Blundell-Bond linear dynamic panel estimation, including year dummies. The coefficients for year dummies and for the constant term are not reported. Standard errors are in parentheses.

* statistical significance at 10%

** statistical significance at 5%

*** statistical significance at 1%.

at the 10 per cent level in the first regression, but negative and statistically significant once we take out the rate of EI coverage, suggesting that there might have been a statistical interaction between the two variables. The negative coefficient of union membership suggests that a higher rate of union membership tends to narrow the productivity-income gap. The coefficient on the rate of growth of the minimum wage is negative and statistically significant in both regressions. This result is expected, since an increase in the minimum wage has both a direct positive effect on the labour income of the workers earning that wage, and a positive influence on the overall fallback of other workers. Finally, the coefficient on the NAFTA dummy is positive and statistically significant in both regressions, suggesting that the agreement indeed had a negative effect on the bargaining power of workers.[22]

Conclusion

Public policies are often predicated on the assumption that real wages rise with productivity growth. If this link between productivity growth and pay were incontrovertible, we would expect pro-productivity policies to be highly popular. Yet, advocates of the productivity agenda are often puzzled that the public views productivity growth with mistrust.

We argue that the link between pay and productivity growth is not automatic in theory. Thus, empirical analysis must assess whether the pay/productivity linkage holds in the Canadian context. We find that Canadian real labour income has increasingly lagged behind productivity growth over recent decades. In addition, evidence suggests that this divergence between productivity growth and real labour income is greater for low-income workers.

Since productivity growth offers the possibility – but not necessity – of real wage growth, we conclude our article with an examination of the conditions in which productivity growth is likely to translate into wage growth. We use a bargaining power approach to argue that the relative bargaining power of employers and employees is important in determining whether employees are capable of translating productivity into real wage growth.

22 Technically speaking, the significance of the estimated coefficient on the dummy variable only tells us that there is a break in the series starting in the mid-1990s. We interpret the estimated coefficient as capturing the effect of the implementation of NAFTA in 1994 given the importance of that accord, but it could also reflect other structural changes that happened in the period, such as the focus on inflation targeting by the Bank of Canada early in the decade.

Bargaining power is influenced by many factors, including the public policy environment in which wage determination takes place. To the extent that bargaining power is shifted toward employers by public policies associated with the productivity agenda, this presents a plausible reason that the concept of productivity, and the efforts by government to boost productivity, are greeted with suspicion. Indeed our econometric analysis suggests that EI reforms, the NAFTA agreement, the behavior of the minimum wage, the unemployment rate, and unionization rates have affected the capacity of workers to reap the benefits of productivity growth. This result is consistent with our hypothesis that public policies associated with the productivity agenda have eroded worker bargaining power, thereby diminishing workers' ability to secure wage gains in tandem with productivity growth.

The bargaining power perspective is a promising approach for future research. For example, it would be worthwhile to investigate the possibility that low-income workers have suffered greater erosion of their bargaining power than higher income workers, thus leading to the differences in average and median earnings depicted in Chart 6. This avenue of exploration may offer important insights into the relation between the dynamics of bargaining power and the larger question of income inequality.

The relationship between public policies intended to boost productivity growth and the real wage/productivity gap suggests a reinterpretation of the productivity agenda for policy-makers. The unpopularity of the productivity agenda is understandable if workers have reason to regard these policies as harming their relative bargaining power. To the extent that the productivity agenda undermines workers' capacity to benefit from any ensuing productivity growth, it is possible that the productivity agenda is generating some of its own headwinds. Policies intended to encourage productivity growth might thus be both more successful and just if they are designed to enable the fruits of productivity growth to be more broadly shared.

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Employment and Productivity: Exploring the Trade-off

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Abstract

The prospect of a trade-off between employment growth and productivity growth may create uncertainty among policy makers who strive to create jobs, and at the same time, seek to improve productivity. This article re-visits the issue. It shows that employment growth may be negatively correlated with productivity growth at the industry level. But this is not a trade-off. It is an outcome of market forces in reallocating production resources to rebalance changes in demand and supply conditions of different industries within an economy. At the aggregate level, employment growth may also be negatively correlated with labour productivity growth through its negative influence on capital intensity and labour quality. But, after controlling for those input factors, this article finds that employment growth does not negatively affect multifactor productivity growth.

Is there a trade-off between employment and productivity? A few studies seem to suggest that this is the case. For instance, Freeman (1988) found that the United States paid for high employment growth with slow growth in labour productivity in comparison with slow employment growth and high labour productivity growth in Europe in the 1970s and 1980s. The employment and labour productivity trade-off is also documented by Cavelaars (2004) for OECD countries in the 1960s and 1970s. More recently, De Michelis *et al.* (2013) present cross-country evidence for a strong negative correlation between multifactor productivity (MFP) growth and labour inputs over the medium to long run. The authors conclude "policies that increase production efficiency at the expense of hours of work and/or employment may result in increased unemployment, loss of income for workers, and reduced overall well-being."[2] The latest study has caught the eyes of many policy analysts and policy makers in Canada as it appeared in the *International Productivity*

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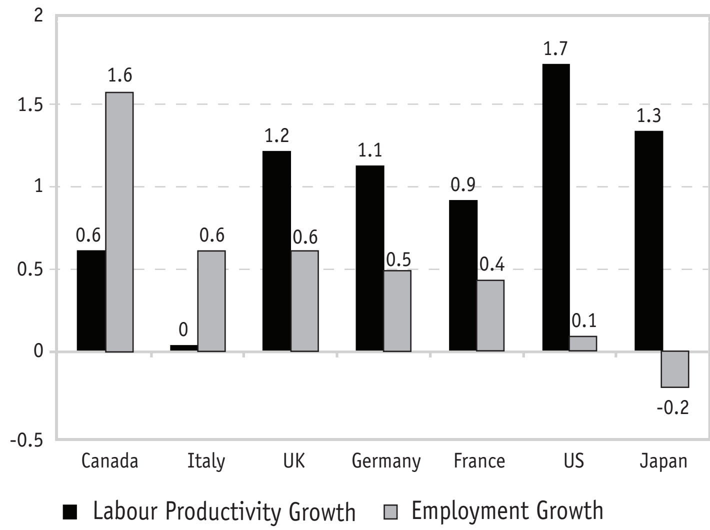
2 In contrast, there have been related empirical studies that have found no such relationship. In studying high labour productivity growth and high unemployment in Europe compared to low labour productivity growth and low unemployment in the United States, Gordon (1995) finds no clear evidence of a trade-off between unemployment and labour productivity growth. He shows that much of the labour productivity growth advantage of the four largest European countries (France, Germany, Italy and the United Kingdom) from 1960 to 1992 over the United States is explained by convergence and by more rapid capital accumulation. In addition, he shows that the only significant effect of higher unemployment is to cause capital accumulation to decelerate, thus reducing the growth rate of labour productivity relative to MFP. Also in a theoretical discussion, Scarth (2005) demonstrates that a policy that addresses inequality via reducing unemployment can also raise productivity.

Chart 1
Total Economy Employment and Labour Productivity (Output per Hour) Growth in G-7 Countries, 2000-2012
(compound annual growth rate)



Sources: OECD, STAT.

Monitor which is widely circulated among Canadian researchers and policy makers.

The view of a trade-off between employment and labour productivity seems to be consistent with the recent observation of a negative correlation between employment growth and labour productivity growth among G-7 countries in the post-2000 period (Chart 1). Over this period, Canada was the best job creator among these countries, with employment growth being the highest, but its labour productivity growth was ranked the second last, only ahead of Italy.

The prospect of a trade-off between the two important economic variables may have undesirable consequences. At the minimum, it may introduce uncertainty and cause hesitation among policy makers. In the words of Scarth (2005), "trade-offs are intimidating to politicians, and as a result, trade-offs make inaction a very tempting strategy."

Is the so-called trade-off between employment and productivity real or artifact? To shed light on this important issue, I re-examine the relationship between employment and productivity. In particular, I focus on the sources of this relationship, which I believe are important for policy makers to better understand and interpret the trade-off between employment and productivity if there is any.

As a starting point, I define a trade-off between two variables as a negative relationship between these variables, that is, an increase in one variable leading to a reduction in the other. In addition, I define a real trade-off between employment and productivity as a negative relationship between employment growth and changes in overall production efficiency (i.e. multifactor productivity growth (MFP)) at the aggregate/national level. I demonstrate theoretically that employment growth may be negatively correlated with productivity growth at the industry level. But this is not a trade-off. It is an outcome of market forces in efficiently reallocating production resources between industries to rebalance the changes in demand and supply conditions of those industries within an economy.

At the aggregate level, for which policy makers care the most, I show that employment growth may indeed be negatively correlated with labour productivity growth. I argue that if this is caused by changes in capital intensity and labour quality, then it is not appropriate to call the negative correlation a trade-off since it is due to the changes in inputs or their combination and does not affect the overall production efficiency (i.e. MFP). Labour productivity is a partial measure of production efficiency. If production becomes more labour intensive, then labour productivity will inevitably be lower. Similarly, when labour quality is reduced because of above-average growth in workers of below-average qualifications, then one would also expect lower labour productivity growth.

After controlling for those input factors, together with country-specific effects and country differences in industry structure and international trade, I find no cross-country empirical evidence that employment growth is negatively correlated with productivity growth.

The remainder of the article is organized as follows. The first section provides a theoretical discussion of the possible channels for the interaction between employment and productivity. Section 2 presents the regression model, describe the data, and discuss the cross-country empirical evidence. The final section concludes.

The Relationship between Employment and Productivity: A Theoretical Discussion

The relationship between productivity growth and job creation depends on many factors. In this article, I focus on the context and discuss how the productivity concept and industry aggregation play important roles in the relationship.

Labour Productivity and MFP

The productivity concept matters for the relationship between employment and productivity. Both labour productivity and MFP are commonly used to measure production efficiency. The former is often defined as output per hour worked. It is a partial measure, only concerning the production efficiency of labour and ignoring capital input. In contrast, MFP is defined as output per unit of combined input (including labour and capital). It measures how efficiently all inputs are used for producing output.

Under the growth accounting framework (e.g., Jorgenson, 2001), which is commonly used for studying economic growth and productivity, the labour productivity function is

$$\Delta \ln LP_t = \Delta \ln MFP_t + \bar{v}_{K,t} \Delta \ln k_t + \bar{v}_{L,t} \Delta \ln q_t \quad (1)$$

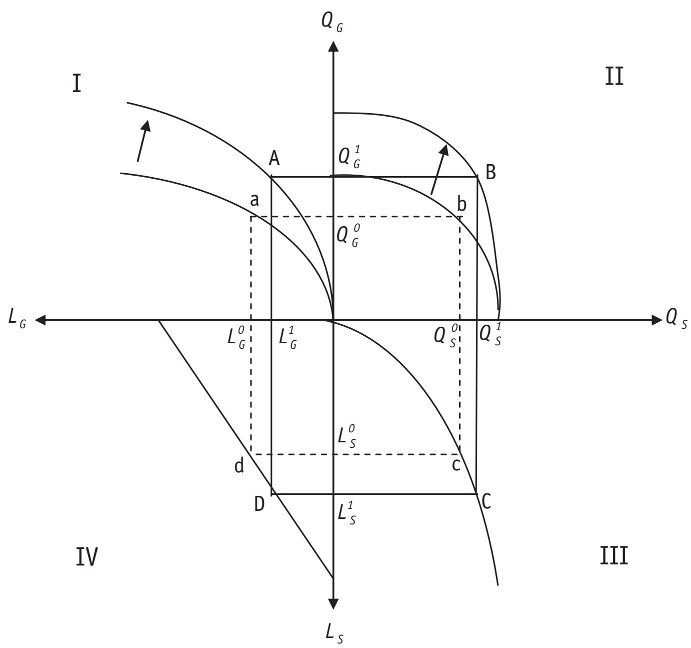
where LP_t is labour productivity, MFP_t is multifactor productivity, k_t is capital intensity (defined as capital input per hour worked), and q_t is labour quality (defined as labour input per hour worked).[3] $\bar{v}_{L,t}$ and $\bar{v}_{K,t}$ are the two-period average labour and capital income shares of value added.

Thus, unlike MFP, labour productivity is influenced by capital intensity and labour quality. It has an important implication for the relationship between productivity and employment. In terms of capital intensity, when labour increases faster than capital due to the substitution of labour for capital (e.g., when labour becomes relatively cheaper than capital) or when the economy shifts from capital-intensive to labour-intensive production, then labour productivity decreases, given constant MFP and labour quality. This will lead to a negative relationship between labour productivity and employment.

Employment growth may also be negatively correlated with labour productivity through its influence on labour quality. Under the growth accounting framework, labour input is commonly adjusted to reflect the composition of the workforce in terms of the gender, age and education levels of workers. It is the sum of hours worked of those different groups, weighted by labour compensation. In other words, hours worked by groups with high labour compensation are weighted more than hours worked by groups with low labour compensation. Compensation here is an indicator for labour quality (or skills). If employment growth is driven by new entrants (e.g., inexperienced young or marginal

3 Capital input is the flow of capital service from quality-adjusted capital stock. Similarly, labour input is hours worked adjusted for work force composition.

Chart 2
Productivity Growth in the "Goods Sector" Creates Jobs in the "Services Sector"



Note: Quadrants I and III are "goods" and "services" production functions, respectively, quadrant II is production possibilities frontier, and quadrant IV is labour demand.

workers) due to improvements in labour market conditions (including labour market programs and institutions) or relative shifts from industries with high paying jobs to industries with low paying jobs, then it will reduce the overall quality of the workforce. This means lower labour productivity growth, leading to a negative relationship between employment growth and labour productivity growth.

In contrast, MFP is measured as a residual – output minus the weighted inputs. It has been controlled for both capital and labour factors, including their quality. Thus, unlike labour productivity, MFP is not directly correlated with employment growth through capital intensity and labour quality.

The term "productivity" in the empirical literature on the relationship between productivity and employment is commonly used to refer to labour productivity (e.g. Freeman 1988; Cavelaars 2004; and Enflo 2010). Thus, a negative relationship between labour productivity and employment is possible, and it is due to a change in the capital-to-labour ratio or due to a change in the composition of the workforce. When all inputs and their quality are counted for, there should be no correlation between employment growth and MFP growth under the framework.

Firm, Industry, and Country

Aggregation also matters. At the firm level, more efficient firms are expected to gain market share and thus hire more employees. This is most likely at the expense of less efficient firms (e.g. Griliches and Regev, 1995). Thus, at the micro level, employment growth is expected to be positively correlated with productivity growth.

At the industry level, however, productivity growth may be negatively correlated with job creation. For example, according to Li *et al.* (2013), the hours worked share of the professional, business, education, health, and social services industries in the Canadian economy (excluding public administration) increased from 18.6 per cent in 1987 to 27.8 per cent in 2010, a 9.2 percentage point increase. In contrast, the share of hours worked in manufacturing decreased 7.4 percentage points from 18.5 per cent to 11.2 per cent. This took place despite stronger labour productivity or MFP growth in manufacturing relative to these services industries. Over the period, labour productivity and MFP annual growth rates in these service industries were on average negative, compared to 2.2 per cent and 1.2 per cent per year respectively for manufacturing.

The change in industry structure and the reallocation of production resources (including labour) from above-average to below-average productivity growth industries is predicted by the theory of unbalanced growth or the "cost disease model" (Baumol, 1967). This can be illustrated by a model of a simple economy with two sectors characterized by different potential productivity paths (Chart 2). Call the high productivity growth sector "the goods sector" and the low productivity growth sector "the services sector". A positive productivity shock in the goods sector shifts the production possibility frontier outward. This causes income to grow and shifts the consumption mix from point b to point B. The increased demand for goods is more than met by the productivity gain in the goods sector and thus less labour ($L_G^1 - L_G^0$) is required. In contrast, more workers ($L_S^1 - L_S^0$) are hired by the low productivity growth services sector to meet the rise in demand for services.

At the aggregate level, the overall change in employment is ($L_S^1 - L_S^0$)-($L_G^1 - L_G^0$). This can be positive or negative, depending on the production technologies used for producing goods and services and the income and competitiveness effects of the positive productivity shock on demand for both goods and services. Typically, the goods sector is capital intensive and the services sector is labour intensive. This may lead to a positive net job creation. However, the relationship needs to be empirically studied.

Cross-country Empirical Evidence

Building on the theoretical discussion, I now conduct an econometric analysis of the relationship between productivity growth and employment growth using cross-country panel data.

Regression Model

To estimate the relationship between productivity growth and employment growth, I set up the following regression model based on equation (1):[4]

$$\begin{aligned}\Delta ln(LP_{i,t}) &= \alpha_{i,0} + \alpha_1 \Delta ln(k_{i,t}) + \alpha_2 \Delta ln(q_{i,t}) \\ &+ \alpha_3 \Delta ln(E_{i,t}) + \alpha_4 GPC_{i,t-1} + \alpha_5 Agrsh_{i,t-1} \\ &+ \alpha_6 Mansh_{i,t-1} + \alpha_7 Minsh_{i,t-1} \\ &+ \alpha_8 Ex_{i,t-1} + \alpha_9 Im_{i,t-1} + \varepsilon_{i,t}^{j}\end{aligned} \qquad (2)$$

Where $\Delta ln(LP_{i,t})$ is labour productivity growth of country *i* between time *t* and *t-1*, with labour productivity being defined as real GDP per hour worked;

$\Delta ln(k_{i,t})$ is capital intensity growth of country *i* between time *t* and *t-1*, with capital intensity being defined as capital input per hour worked;

$\Delta ln(q_{i,t})$ is labour quality/composition growth of country *i* between time *t* and *t-1*, with labour quality being defined as labour input per hour worked;

$\Delta ln(E_{i,t})$ is employment growth of country *i* between time *t* and *t-1*;

$GPC_{i,t-1}$ is GDP per capita (PPP-based) at the beginning of the period or time *t-1*;

$Agrsh_{i,t-1}$, $Mansh_{i,t-1}$, and $Minsh_{i,t-1}$ are the shares of agriculture, manufacturing and mining sectors in nominal GDP of country *i* at the beginning of the period or time *t-1*;[5]

$Ex_{i,t-1}$ and $Im_{i,t-1}$ are export and import intensities (export/import values as a percentage of nominal GDP) of country *i* at the beginning of the period or time *t-1*; and

$\varepsilon_{i,t}$ is the error term.

The regression model departs from the empirical literature on the trade-off between

4 The regression with productivity as the dependent variable and employment as the independent variable is the most commonly used in the empirical literature on the relationship between employment and productivity. A regression model with employment as the dependent variable and productivity the independent variable is difficult to specify since there are many factors affecting labour demand. Nevertheless, I tried regressions of employment growth against productivity growth while controlling for other factors such as country-specifics, industry structure and trade, and found no evidence of a negative relationship between them.

5 Regression results do not change significantly when hours worked shares are used.

productivity and employment in several aspects. First, I regress labour productivity growth against employment growth while controlling for capital intensity and labour quality, which is basically a regression of MFP growth against employment growth. Most empirical studies on this topic have so far relied on simple regressions of labour productivity growth against employment growth without controlling for capital intensity and labour quality.[6]

Second, I control for industry structure ($Agrsh_{i,\,t-1}$, $Mansh_{i,\,t-1}$, and $Minsh_{i,\,t-1}$). At the aggregate level, the industry structure may play a role in the relationship between productivity and employment. After all, the aggregate productivity level is calculated from industry-specific productivity levels and the industry structure or mix of the economy (Tang, 2014). It is expected that an economy relying on, for example, the goods sector, will have a different relationship between productivity and employment than another economy concentrated in, for example, the services sector due to varying industry productivity performance and different production technologies across industries.

Third, I control for export and import intensities (export/import values as a percentage of nominal GDP). In the global economy, demand conditions for an economy or an industry are influenced by the external forces or international trade, especially for small open economies. Canada's manufacturing and mining sectors are typical examples. In the post-2000 period, the weak U.S. economy, increased competition from low-cost producing countries, and the appreciation of the Canadian dollar significantly reduced the demand for certain manufactured goods in Canada, leading to a shrinking manufacturing sector. At the same time, the rise of emerging economies has increased the demand for commodities, resulting in a booming mining sector in Canada. The change in demand conditions associated with international trade will affect economies of scale and the utilization of production resources (labour and capital), which in turn will affect productivity. For example, Baldwin *et al.* (2013) show that almost all of the productivity growth slowdown in the Canadian manufacturing sector in the post-2000 period was driven by the fall in exports.

Fourth, unlike most previous studies on the trade-off between employment and productivity which do not consider country fixed effects, I introduce a country-specific variable to control for country-specific factors such as demographic and geographic factors, resource endowment, institutions, infrastructure, competition policy, corporate governance, business/marketplace framework, labour market conditions, financial system, monetary policy and fiscal policies.[7] For instance, Bloom and Van Reenen (2007) find significant cross-country differences in corporate management practice, with U.S. firms being better managed than those in many other countries.

Finally, I control for country income levels, approximated by GDP per capita. This control is introduced to capture the convergence or catch-up effect. It has been hypothesized that poor countries tend to grow faster than rich countries. They achieve this through replication of the production methods, technologies and institutions of rich countries. The convergence also reflects slower growth in high income countries due to the diminishing returns of capital in these countries. The sign of the variable is expected to be negative.

6 De Michelis *et al.* (2013) are an exception, using MFP instead of labour productivity. However, their results are based on regressions with 20 or fewer observations, and consequently, should be interpreted with caution.

7 I choose a model with fixed instead of random effects since country-specific heterogeneity in the model might also be correlated with some regressors such as capital intensity and labour quality.

Table 1
List of Countries and the Years with Data

Country	Unbalanced Sample	Balanced Sample 1973-2007	Relative Richness (GDP per capita)	Relative Size (GDP)
Australia	1982-2007		Rich	Large
Austria	1980-2009		Rich	Small
Belgium	1986-2009		Rich	Small
Canada	1970-2008	Yes	Rich	Large
Czech Republic	1995-2007		Poor	Small
Denmark	1980-2007		Rich	Small
Finland	1970-2007	Yes	Rich	Small
France	1980-2009		Rich	Large
Germany	1991-2009		Rich	Large
Greece	1992-2007		Poor	Small
Hungary	1995-2007		Poor	Small
Ireland	1988-2007		Rich	Small
Italy	1972-2009	Yes	Rich	Large
Japan	1973-2009	Yes	Rich	Large
Korea	1989-2007		Poor	Large
Netherlands	1988-2009		Rich	Large
Poland	1995-2007		Poor	Large
Portugal	1989-2007		Poor	Small
Slovak Republic	1995-2007		Poor	Small
Slovenia	1995-2007		Poor	Small
Spain	1980-2009		Poor	Large
Sweden	1993-2007		Rich	Small
United Kingdom	1972-2009	Yes	Rich	Large
United States	1970-2009	Yes	Rich	Large

Note: The grouping of the "rich" and the "poor" is based on average GDP per capita (constant PPP-adjusted price) over the 1995-2007 period. The grouping of the "small" and the "large" is based on the average size of GDP (PPP-based) over the 1995-2007 period.

Data

The data for our empirical analyses are mainly from EUKLEMS and World KLEMS databases.[8] These databases are developed, as a joint effort by OECD member countries, to ensure consistent and reasonable comparable production data for cross-country studies of productivity and economic growth. I extracted data on both outputs and inputs, including value added (both nominal and real), labour (quality-adjusted labour input, employment, hours worked, and labour compensation), and capital (capital input and capital compensation).[9] These data are supplemented by OECD data on GDP (PPP-based), export, import, total population, and working population. As a result, I obtained an unbalanced panel data for 24 countries over the 1970-2009 period. The list of countries and the number of observations for each of them are reported in Table 1.[10]

8 See O'Mahony and Timmer (2009) on the EUKLEMS program and Jorgenson (2012) on the World KLEMS initiative.

9 For some countries, data on capital input and labour input are not available from either EUKLEMS or World KLEMS. The missing data (i.e, capital input for Greece, Korea, Poland, Portugal and the Slovak Republic and labour input for Poland and Portugal) are replaced by data from the total economy database of the U.S. Conference Board. For Slovenia, output, capital and labour data are extended one more year to 2007 using data based on the total economy database.

10 Many countries are constrained by a lack of capital input data. When capital input is not required, the sample size increases substantially.

Chart 3

Simple Correlation between Labour Productivity Growth and Employment Growth for 24 OECD Countries, 1995-2007

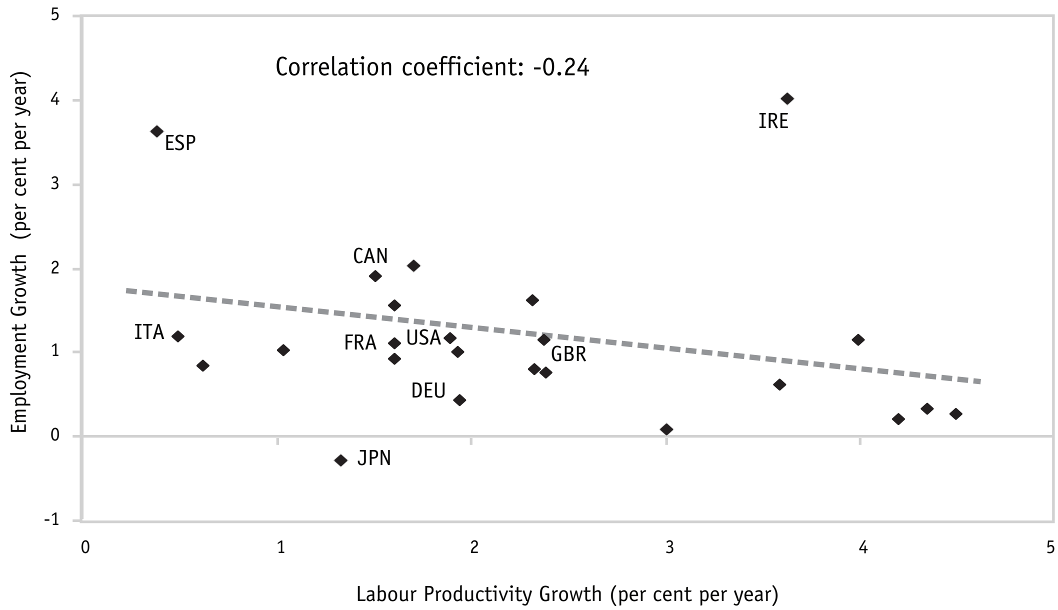
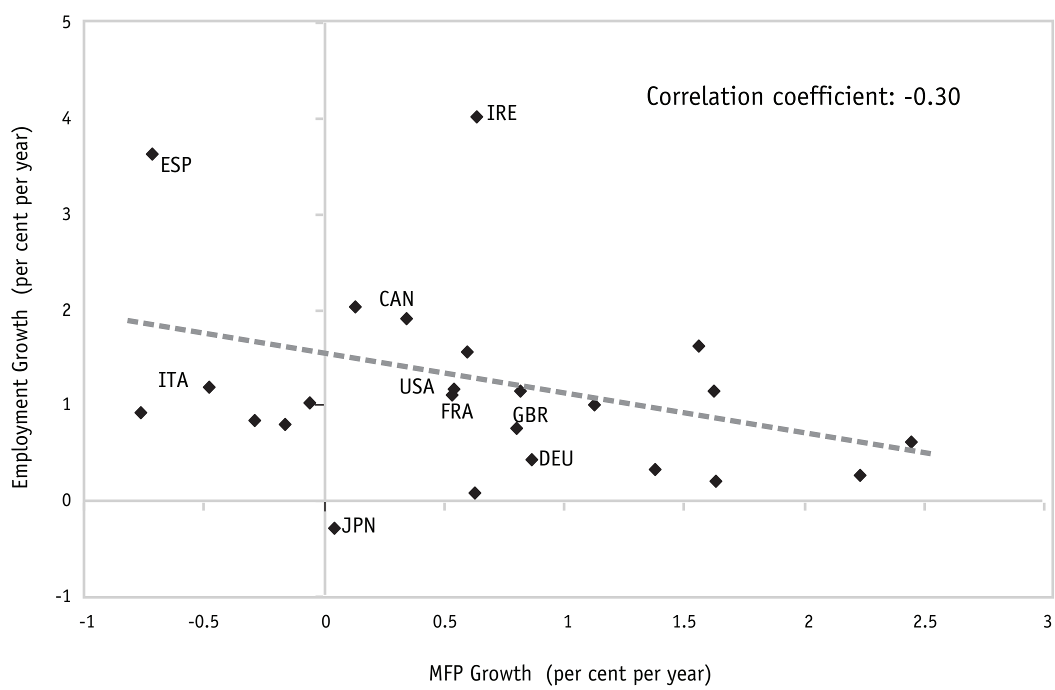


Chart 4

Simple Correlation between MFP Growth and Employment Growth for 24 OECD Countries, 1995-2007



Simple Correlation between Productivity Growth and Employment Growth

All 24 countries had data for the 1995-2007 period. Over this period, both labour productivity growth and MFP growth were negatively correlated with employment growth, as illustrated in Charts 3 and 4, respectively.[11] It is interesting to note that over the period, Canada outperformed many other countries including all other G7 nations in employment growth, but underperformed most of the countries in productivity growth. This is similar to the observation for the post-2000 period (Chart 1).

The correlation coefficient between labour productivity growth and employment growth was -0.24. Ireland is an outlier. When it was excluded, the coefficient was -0.50. For MFP growth, the correlation coefficient was -0.30 (or -0.38 when Ireland was excluded). The finding of a negative relationship between both labour productivity and multifactor productivity growth and employment growth is similar to that found by De Michelis *et al.* (2013) based on 20 OECD countries for the 1970-2007 period.

However, the simple correlation that quantifies the association between labour productivity growth and employment growth should not be interpreted as a trade-off without further investigation. The association does not control for other factors that may influence the interdependence of the two variables. For instance, it neither controls for capital intensity and labour quality (for labour productivity) nor for country-specific effects, industry structure and international trade.

To provide a vigorous analysis of the dependence of one variable on another variable with control for other factors, an econometric analysis is required.

Discussion of Regression Results

I first regress labour productivity growth against employment growth, using the unbalanced panel data for 24 OECD countries for the 1970-2009 period. The panel least square estimation shows that employment growth was negatively correlated with labour productivity growth, and the estimated coefficient was statistically significant at the 5 per cent level (Table 2, Column 1).

The regression, however, has very limited explaining power since the adjusted R-square was almost zero. For the next regression, column (2), I control for country-specific effects. The estimation shows that employment growth was negative and significant. The adjusted R-square increased significantly to 0.15. This suggests that country-specific conditions were important for productivity growth. The results continue to hold after correcting for auto-correlation (i.e. a productivity shock in the previous period is affecting productivity growth in the current period), as shown in Column (3). The result is in line with the prediction that employment growth is negatively correlated with labour productivity through its impact on capital intensity and labour quality, as discussed earlier.

In regression (4), I add controls for growth in capital intensity and labour quality. The two added variables were positive and significant, especially growth in capital intensity. Most importantly, however, employment growth was now positive and highly significant, indicating employment growth was moving in the same direction as productivity growth.

I then control for GDP per capita (PPP-based), industry structure, and international trade in regressions (5) and (6). These two new regressions continue to show that employment growth was positively correlated

11 MFP growth is calculated as labour productivity growth minus the contributions from changes in capital intensity and labour quality, as shown in equation (1).

Table 2

Regressions of Labour Productivity Growth against Employment Growth

(annual rate, unbalanced panel data with 24 OECD countries for 1970-2009)

	Panel Least Squares						GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Constant	0.026 (0.002)***	0.026 (0.002)***	0.025 (0.002)***	0.001 (0.003)	0.527 (0.135)***	0.538 (0.147)***	0.497 (0.142)***
Capital intensity growth				0.468 (0.047)***	0.469 (0.047)***	0.498 (0.066)***	0.450 (0.052)***
Labour quality growth				0.167 (0.093)*	0.150 (0.090)*	0.147 (0.082)*	0.145 (0.088)
Employment growth	-0.166 (0.080)**	-0.220 (0.092)**	-0.218 (0.112)*	0.243 (0.066)***	0.258 (0.066)***	0.244 (0.066)***	0.063 (0.133)
Lagged GDP per capita					-0.064 (0.017)***	-0.070 (0.018)***	-0.064 (0.017)***
Lagged agriculture share					-0.022 (0.008)***	-0.020 (0.008)**	-0.018 (0.008)**
Lagged manufacturing Share					-0.017 (0.015)	-0.032 (0.015)**	-0.025 (0.015)*
Lagged mining share					-0.003 (0.004)	-0.003 (0.003)	-0.003 (0.003)
Lagged export intensity						0.044 (0.010)***	0.044 (0.010)***
Lagged import intensity						-0.050 (0.012)***	-0.051 (0.012)***
AR(1)			0.262 (0.075)***	0.297 (0.057)***	0.342 (0.064)***	0.359 (0.063)***	0.346 (0.062)***
Country-fixed effect	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	792	792	768	548	540	536	536
Adjusted R-squared	0.01	0.15	0.20	0.45	0.47	0.50	0.49

Note: The White cross-section standard error is reported in the parenthesis, with "*", "**", and "***" denoting significance at 10%, 5% and 1%, respectively. The instrument variables for employment growth in regression (7) are working population growth and lagged tax rate (tax revenue as percentage of GDP).

with productivity growth. Note, however, that GDP per capita was negative and highly significant. This suggests that there was a convergence or catch-up effect with relatively poor countries experiencing faster productivity growth than relatively rich countries. In addition, the estimation shows that countries that relied on agriculture or imports had lower productivity growth, while those with higher export intensity had higher productivity growth.[12]

No matter the direction of causality, a positive relationship between growth in employment and labour productivity indicates that there is no trade-off between the two variables. However, in the final regression, Column (7), I estimate the regression model using the general method of moments (GMM) to ensure unbiased estimation. The estimation deals with the endogeneity issue not only due to the causality from productivity growth to employment growth but also due to missing

12 The estimation also shows that countries with a higher manufacturing share tended to have lower productivity growth than other countries, but the result was not robust for some sub-samples, which will be discussed later on.

Table 3
Regressions of Labour Productivity Growth against Employment Growth
(annual rate, balanced panel data with 6 OECD countries for 1973-2007)

	Panel Least Squares						GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Constant	0.021 (0.002)***	0.020 (0.002)***	0.021 (0.002)***	0.003 (0.003)	0.740 (0.229)***	0.665 (0.221)***	0.638 (0.218)***
Capital intensity growth				0.371 (0.047)***	0.405 (0.030)***	0.410 (0.020)***	0.387 (0.032)***
Labour quality growth				0.631 (0.122)***	0.507 (0.110)***	0.587 (0.102)***	0.599 (0.104)***
Employment growth	-0.171 (0.071)**	-0.090 (0.074)	-0.096 (0.090)	0.168 (0.126)	0.235 (0.100)**	0.223 (0.099)**	0.100 (0.157)
Lagged GDP per capita					-0.093 (0.028)***	-0.086 (0.026)***	-0.083 (0.025)***
Lagged agriculture share					-0.031 (0.011)***	-0.021 (0.010)**	-0.021 (0.010)**
Lagged manufacturing Share					-0.041 (0.019)**	-0.053 (0.018)***	-0.047 (0.019)**
Lagged mining share					-0.006 (0.004)	-0.007 (0.004)*	-0.007 (0.004)*
Lagged export intensity						0.044 (0.011)***	0.043 (0.011)***
Lagged import intensity						-0.048 (0.011)***	-0.048 (0.011)***
AR(1)			0.271 (0.101)***	0.228 (0.096)**	0.314 (0.097)***	0.306 (0.081)***	0.304 (0.089)***
Country-fixed effect	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	204	204	198	198	198	198	198
Adjusted R-squared	0.02	0.06	0.13	0.45	0.49	0.55	0.54

Note: The White cross-section standard error is reported in the parenthesis, with "*", "**", and "***" denoting significance at 10%, 5% and 1%, respectively. The instrument variables for employment growth in regression (7) are working population growth and lagged tax rate (tax revenue as percentage of GDP).

variables that are correlated with employment growth. I use working-age population growth and lagged tax rate (total tax revenue as percentage of GDP) as the instrument variables.[13] The GMM estimation continues to show that employment growth was positively linked to labour productivity growth, although the relationship became statistically insignificant.

Robustness of the Regression Results

In the remainder of the article, I conduct additional regressions to check the robustness of the above regression results associated with the relationship between employment growth and productivity growth. The effort does not intend to be exhaustive. Instead, it provides some evi-

13 Working population growth and lagged tax rate are found to be correlated with employment growth. The estimated coefficients of employment growth against working population growth and lagged tax rate are 0.904 and -0.012, being significant at 1 percent and 10 percent levels respectively. In contrast, the estimated coefficients of productivity growth against those two instrumental variables are insignificant (0.005 and -0.002, respectively). In addition, a J test for overidentifying restrictions indicates that the instrument variables are uncorrelated with the error process.

Table 4
Regressions of Labour Productivity Growth against Employment Growth
(Annual Rate, Unbalanced Panel Data with Relatively Rich vs. Poor Countries, 1970-2009)

	Relatively Rich Countries			Relatively Poor Countries		
	Panel Least Squares		GMM	Panel Least Squares		GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	-0.001 (0.003)	0.612 (0.159)***	0.620 (0.175)***	-0.003 (0.005)	0.714 (0.319)***	0.607 (0.307)***
Capital intensity growth	0.427 (0.035)***	0.446 (0.048)***	0.398 (0.033)***	0.627 (0.093)***	0.813 (0.068)***	0.746 (0.091)***
Labour quality growth	0.650 (0.156)***	0.564 (0.122)***	0.559 (0.127)***	-0.019 (0.028)	-0.017 (0.041)	-0.015 (0.042)
Employment growth	0.210 (0.085)**	0.189 (0.077)**	-0.055 (0.151)	0.366 (0.081)***	0.436 (0.060)***	0.300 (0.156)*
Lagged GDP per capita		-0.081 (0.019)***	-0.082 (0.020)***		-0.078 (0.040)*	-0.063 (0.039)
Lagged agriculture share		-0.023 (0.009)***	-0.024 (0.010)**		-0.051 (0.018)***	-0.044 (0.018)**
Lagged manufacturing Share		-0.040 (0.016)**	-0.032 (0.017)*		0.016 (0.031)	0.021 (0.030)
Lagged mining share		-0.004 (0.003)	-0.004 (0.002)*		0.003 (0.021)	0.005 (0.021)
Lagged export intensity		0.037 (0.009)***	0.037 (0.009)***		0.101 (0.031)***	0.099 (0.032)***
Lagged import intensity		-0.047 (0.010)***	-0.047 (0.011)***		-0.095 (0.033)***	-0.093 (0.034)***
AR(1)	0.255 (0.065)***	0.304 (0.068)***	0.316 (0.068)***	0.347 (0.081)**	0.507 (0.107)***	0.471 (0.110)***
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	417	409	309	131	127	127
Adjusted R-squared	0.42	0.49	0.47	0.51	0.58	0.57

Note: The White cross-section standard error is reported in the parenthesis, with "*", "**", and "***" denoting significance at 10%, 5% and 1%, respectively. The instrument variables for employment growth in regressions (3) and (6) are working population growth and lagged tax rate (tax revenue as percentage of GDP).

dence that the empirical results are fairly robust for different groups of the sample.

Balanced Panel

The econometric analysis has so far been based on an unbalanced panel with 24 countries in the 1970-2010 period. Most missing observations are from low income countries in the early years of this period as shown in Table 1. The specific pattern indicates that the observations were not missing at random, which may lead to biased and inconsistent estimation results.

To see if the unbalanced panel being not random is an issue for our results, I re-estimate the regressions in Table 2, using a balanced panel with six countries for 1973-2007, extracted from the unbalanced panel. The six countries are Canada, Finland, Italy, Japan, the United Kingdom, and the United States.

The new estimation results were in general similar to those based on the unbalanced panel (Table 3). They continue to show that employment growth was positively correlated with productivity growth after controlling for capital intensity, labour quality, industry structure, and international trade, although it was not significant when the GMM was used (Table 3). For regressions with these six countries, I observe that labour quality became highly significant and that the sum of the estimated coefficients on capital intensity and labour quality was very close to unity. This might suggest higher quality production data for those countries.

Relatively Rich Countries vs Relatively Poor Countries

The estimation has so far been based on data from a mix of 24 high income and low income OECD countries. Rich countries tend to be more developed than poor countries in many aspects, including labour market policies, programs and institutions. Can the estimation results be generalized to either rich or poor countries? To address this question, I divide the 24 countries into the "rich" and the "poor," based on average GDP per capita (constant PPP-adjusted price) over the 1995-2007 period. The 15 countries with the highest average levels of GDP per capita are labeled the "rich" and the remaining 9 countries are the "poor" (Table 1). I have more rich than poor countries since I am more comfortable to include France, Italy and Finland in the rich camp. They will otherwise be in the poor camp when equal number countries in the two groups are forced.

The division of the sample did not change our main result, that is, employment growth was not negatively and significantly correlated with productivity growth for both groups of countries (Table 4). On the contrary, most of the regressions show that the relationship was positive and significant, especially for the relatively poor countries.

For the relatively rich countries, labour productivity growth was significantly correlated with both capital intensity growth and labour quality growth; however, for the relatively poor countries, it was only significantly correlated with capital intensity growth. The result on labour quality for the two groups of countries might also indicate that the labour quality estimate was too noisy for the relatively poor countries. Note also that the catch-up effect was very strong among the relatively rich countries, but was only marginal for the relatively poor countries.

1970-1994 vs 1995-2010

The relationship between employment growth and productivity growth may change from one period to another due to changes in labour market conditions and globalization. To see if this is the case in the first half of the sample period compared to the second half of the sample period, I divide the whole sample period into two sub-periods: 1970-1994 and 1995-2010. The division allows enough observations for each sub-period. I re-run the regressions independently. The estimation shows that there was no significant change in the relationship between employment growth and labour productivity growth between the 1970-1994 and 1995-2010 sub-periods. Most importantly, the estimation shows that employment growth was positively correlated with labour productivity growth although the relationship was not significant when the GMM is used.

The estimation also shows that labour quality was positive, but only highly significant for the 1970-1994 sub-period (Table 5). The result is consistent with the early estimation showing that labour quality was only significant for the relatively rich countries since most of the relatively poor countries do not have observations for the 1970-1994 sub-period.

Small vs Large

Does country size matter? When a country is small, its economy may be relatively concentrated in certain sectors, for example, high-tech (Nokia) in Finland and mining and oil and gas in Canada. As a result, both productivity and employment in small countries might be more volatile and sensitive to specific shocks. To check the sensitivity of the relationship between employment growth and productivity growth, I

Table 5
Regressions of Labour Productivity Growth against Employment Growth
(annual rate, unbalanced panel data 1970-1994 vs 1995-2009)

	1970-1994			1995-2010		
	Panel Least Squares		GMM	Panel Least Squares		GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	-0.001 (0.005)	0.812 (0.165)***	0.739 (0.145)***	0.001 (0.003)	0.359 (0.293)	0.363 (0.298)
Capital intensity growth	0.487 (0.124)***	0.677 (0.084)***	0.537 (0.089)***	0.432 (0.050)***	0.455 (0.066)***	0.460 (0.080)***
Labour quality growth	0.459 (0.109)***	0.320 (0.121)***	0.403 (0.122)***	0.100 (0.092)	0.091 (0.078)	0.093 (0.093)
Employment growth	0.189 (0.095)**	0.391 (0.089)***	0.135 (0.136)	0.284 (0.084)***	0.266 (0.074)***	0.292 (0.228)
Lagged GDP per capita		-0.112 (0.020)***	-0.099 (0.016)***		-0.051 (0.029)*	-0.052 (0.030)*
Lagged agriculture share		-0.031 (0.012)***	-0.026 (0.010)**		-0.019 (0.007)***	-0.019 (0.007)***
Lagged manufacturing Share		-0.107 (0.030)***	-0.086 (0.025)***		-0.009 (0.016)	-0.011 (0.022)
Lagged mining share		0.000 (0.004)	0.000 (0.004)		-0.011 (0.005)**	-0.012 (0.005)**
Lagged export intensity		0.047 (0.011)***	0.044 (0.011)***		0.056 (0.018)***	0.056 (0.017)***
Lagged import intensity		-0.053 (0.012)***	-0.051 (0.013)***		-0.060 (0.022)***	-0.059 (0.020)***
AR(1)	0.213 (0.072)***	0.182 (0.076)***	0.154 (0.074)**	0.278 (0.097)**	0.304 (0.120)***	0.302 (0.101)***
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	241	235	235	307	301	301
Adjusted R-squared	0.37	0.56	0.53	0.52	0.55	0.55

Note: The White cross-section standard error is reported in the parenthesis, with "*", "**", and "***" denoting significance at 10%, 5% and 1%, respectively. The instrument variables for employment growth in regressions (3) and (6) are working population growth and lagged tax rate (tax revenue as percentage of GDP).

divided equally the 24 countries in our sample into two groups based on average size of GDP (PPP-based) over the 1995-2007 period. The division is listed in Table 1.

Again, there was no evidence of a significant negative correlation between employment growth and labour productivity growth for either large or small countries (Table 6).

MFP Growth as the Dependant Variable

To establish a linkage between employment growth and productivity growth, I can directly regress MFP growth against employment growth. As shown in Equation (1), MFP growth is calculated as labour productivity growth minus contributions from growth in capital intensity and labour quality. The advantage of such a new regression is that it can eliminate any multi-collinearity problem of employment with capital intensity and labour quality, although this is not expected to be a significant issue since the correlation of employment growth with growth in capital intensity was -0.32 and -0.06 for growth in labour quality. The disadvantage is that I lose

Table 6

Regressions of Labour Productivity Growth against Employment Growth

(annual rate, unbalanced panel data, small vs large countries, 1970-2009)

	Large			Small		
	Panel Least Squares		GMM	Panel Least Squares		GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	-0.002 (0.004)	0.581 (0.166)***	0.479 (0.154)***	0.005 (0.004)	0.364 (0.244)	0.365 (0.247)
Capital intensity growth	0.483 (0.063)***	0.497 (0.083)***	0.427 (0.057)***	0.447 (0.095)***	0.498 (0.082)***	0.522 (0.084)***
Labour quality growth	0.236 (0.155)	0.206 (0.140)	0.187 (0.152)	0.068 (0.068)	0.032 (0.077)	0.027 (0.077)
Employment growth	0.265 (0.092)***	0.206 (0.140)	-0.053 (0.140)	0.191 (0.122)	0.210 (0.145)	0.268 (0.155)*
Lagged GDP per capita		-0.077 (0.020)***	-0.064 (0.019)***		-0.047 (0.026)*	-0.048 (0.027)*
Lagged agriculture share		-0.030 (0.013)**	-0.022 (0.013)*		-0.003 (0.009)	-0.003 (0.009)
Lagged manufacturing Share		-0.026 (0.017)	-0.018 (0.017)		-0.033 (0.028)	-0.036 (0.027)
Lagged mining share		0.000 (0.004)	-0.000 (0.004)		-0.008 (0.005)*	-0.008 (0.005)*
Lagged export intensity		0.031 (0.008)***	0.031 (0.008)***		0.068 (0.022)***	0.069 (0.022)***
Lagged import intensity		-0.040 (0.010)***	-0.041 (0.010)***		-0.070 (0.022)***	-0.071 (0.022)***
AR(1)	0.243 (0.086)	0.303 (0.072)***	0.266 (0.075)***	0.357 (0.067)**	0.346 (0.082)***	0.346 (0.084)***
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	330	329	329	218	207	207
Adjusted R-squared	0.48	0.54	0.50	0.37	0.39	0.39

Note: The White cross-section standard error is reported in the parenthesis, with "*", "**", and "***" denoting significance at 10%, 5% and 1%, respectively. The instrument variables for employment growth in regressions (3) and (6) are working population growth and lagged tax rate (tax revenue as percentage of GDP).

the flexibility in the elasticities of output with respect to capital and labour. In addition, I have to implicitly assume constant returns to scale production and elasticities of output with respect to capital and labour being their income shares respectively.

The regression results are reported in Table 7. They are in general similar to the findings based on labour productivity growth as the dependent variable. They show that employment growth was not negatively and significantly correlated with multifactor productivity growth.

Regressions with Growth over a Five-Year Period

The relationship between employment growth and productivity growth may also be subject to cyclical factors and measurement issues, which may dominate any trend change over a short period, as pointed out by Blanchard (2004). To minimize the potential problem, I re-estimated the regression model of labour productivity growth against employment growth, based on a five-year average growth rate instead of an annual growth rate. The regression results are reported in Table 8.[14]

14 I also performed the same exercise based on the balanced panel data for the six countries. Similar results were obtained.

Table 7
Regressions of MFP Growth against Employment Growth
(annual rate, unbalanced panel data with 24 OECD countries for 1970-2009)

	Panel Least Squares					GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	0.004 (0.001)***	0.004 (0.001)***	0.003 (0.002)*	0.486 (0.012)***	0.503 (0.124)***	0.475 (0.125)***
Employment growth	0.106 (0.060)*	0.143 (0.062)**	0.174 (0.061)***	0.189 (0.060)***	0.170 (0.057)***	-0.000 (0.107)
Lagged GDP per capita				-0.056 (0.015)***	-0.061 (0.015)***	-0.057 (0.015)***
Lagged agriculture share				-0.020 (0.007)***	-0.017 (0.007)**	-0.016 (0.007)**
Lagged manufacturing Share				-0.010 (0.014)	-0.023 (0.014)	-0.018 (0.014)
Lagged mining share				0.000 (0.003)	0.000 (0.003)	-0.000 (0.003)
Lagged export intensity					0.034 (0.009)***	0.037 (0.009)***
Lagged import intensity					-0.037 (0.010)***	-0.041 (0.010)***
AR(1)			0.215 (0.072)***	0.204 (0.076)***	0.213 (0.077)***	0.219 (0.083)***
Country-fixed effect	No	Yes	Yes	Yes	Yes	Yes
Observations	570	570	546	539	535	535
Adjusted R-squared	0.01	0.11	0.13	0.16	0.19	0.17

Note: The White cross-section standard error is reported in the parenthesis, with "*", "**", and "***" denoting to be significant at 10%, 5% and 1%, respectively. The instrument variables for employment growth in regressions (3) and (6) are working population growth and lagged tax rate (tax revenue as percentage of GDP).

Interestingly, for the first time, employment growth was negative and significant, after controlling for growth in capital intensity and labour quality, as shown in regression (5). However, after dealing with the potential endogeneity issue associated with employment growth, the GMM estimation, regression (6), shows that employment growth was positive, although it was insignificant. Thus, the new regression results are in general consistent with previous findings.

Notably, the linkage of labour productivity with capital intensity or labour quality now breaks down. This limited evidence may suggest that the relationship between output and inputs are more on a contemporary basis. In other words, regressions based on annual growth rates may fit the data better than those based on average five-year growth rates, a conjecture requiring further research.

Conclusion

A number of empirical studies on economic performance suggest that there is a trade-off between employment and productivity. If true, the trade-off stands to be a great challenge for policy makers who strive to boost economic growth through job creation and productivity improvement.

I re-visited the prospect of a trade-off between employment and productivity, and in particular examined the sources of this relationship. I theoretically demonstrated that employment growth and productivity growth may be

Table 8

Regressions of Labour Productivity Growth against Employment Growth

(5-year rate, unbalanced panel data with 24 OECD countries for 1970-2009)

	Panel Least Squares					GMM
Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	0.102 (0.008)***	0.105 (0.010)***	0.039 (0.009)***	0.707 (0.321)**	0.563 (0.369)	0.450 (0.484)
Capital intensity growth			0.257 (0.054)***	0.093 (0.094)	0.124 (0.110)	0.202 (0.197)
Labour quality growth			0.390 (0.310)	0.240 (0.266)	0.230 (0.330)	0.305 (0.384)
Employment growth	-0.086 (0.059)	-0.162 (0.053)***	0.058 (0.068)	-0.105 (0.076)	-0.142 (0.057)**	0.054 (0.341)
Lagged GDP per capita				-0.070 (0.035)*	-0.064 (0.036)*	-0.046 (0.051)
Lagged agriculture share				0.223 (0.361)	0.452 (0.362)	0.213 (0.594)
Lagged manufacturing Share				-0.032 (0.041)	-0.034 (0.040)*	-0.022 (0.046)
Lagged mining share				-0.002 (0.007)	-0.004 (0.007)*	0.002 (0.011)
Lagged export intensity					0.028 (0.046)	0.021 (0.047)
Lagged import intensity					-0.038 (0.047)	-0.025 (0.046)
Country-fixed effect	No	Yes	Yes	Yes	Yes	Yes
Observations	188	188	123	121	120	120
Adjusted R-squared	0.00	0.26	0.57	0.62	0.61	0.59

Note: The White cross-section standard error is reported in the parenthesis, with "*", "**", and "***" denoting to be significant at 10%, 5% and 1%, respectively. The instrument variables for employment growth in regression (6) are working population growth and lagged tax rate (tax revenue as percentage of GDP).

negatively correlated at the industry level, along the lines of Baumol's "cost disease model," which predicts that lower productivity growth industries tend to absorb employment released from high productivity growth industries. This, however, is not a real trade-off between employment and productivity. It is an outcome of market forces in reallocating production resources between industries to rebalance the changes in demand and supply conditions of the industries within an economy.

Employment growth may also be negatively correlated with labour productivity growth, even at the aggregate level. But the relationship should not be viewed as a trade-off between production efficiency and employment. Labour productivity is a partial measure of production efficiency, and it is expected to be influenced when employment growth changes capital intensity and labour quality.[15] But when those input factors are controlled for, employment growth is not expected to be negatively correlated with the broader measure of production efficiency, MFP growth.

Using KLEMS data for 24 OECD countries, I empirically showed that at the aggregate level there is no evidence of a negative relationship between employment growth and labour productivity growth, after controlling for capital intensity, labour quality, industry structure, and

15 This is consistent with the finding by Boulhol and Turner (2009).

international trade. This finding was robust for rich or poor countries, small or large, and over the pre- or post-1995 period.

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Contribution of ICT Diffusion to Labour Productivity Growth: The United States, Canada, the Eurozone, and the United Kingdom, 1970-2013

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Abstract

This study measures and compares the trends in ICT diffusion and the contribution of ICT to labour productivity growth in the United States, Canada, the Eurozone, and the United Kingdom from 1970 to 2013. There are three main results: i) after a long period of sustained growth, ICT diffusion, as measured by the share of ICT capital stock to GDP expressed in current prices, has stabilized since 2000 in all four areas; ii) this stabilization happened at different levels, significantly higher in the United States than elsewhere; and iii) in all four jurisdictions, the contribution of ICT to labour productivity growth rose significantly in 1994-2004 compared to 1974-1994. Since 2004, the contribution of ICT to labour productivity growth has fallen off considerably. It only remains positive as a result of the continued advances in ICT performance as proxied by the continued fall in ICT prices. Unfortunately, the pace of improvement also appears to be rapidly decreasing.

Ample empirical literature has been dedicated to the analysis of the diffusion of information and communication technologies (ICT) and the contribution of ICT to economic growth.[2] This study characterizes and compares the evolution of ICT diffusion and the contribution of ICT to labour productivity growth. It shows that ICT diffusion continuously increased until the 2000s and then stabilized or slightly declined. As in Cette and Lopez (2012), we demonstrate that ICT diffusion, as a factor of production in advanced countries, stabilized in the beginning of the 2000s at a higher level in the United States than in the other countries studied. We also found that the contribution of ICT to labour productivity was higher in the United States. Moreover, our results are consistent with those of Byrne *et al.* (2013) showing that the contribution of ICT to labour productivity growth sharply fell in the United States starting in the middle of the 2000s before the most recent crisis.

1 The authors would like to thank Andrew Sharpe and two anonymous referees for comments. The authors would also like to thank Dirk Pilat, Belen Zinni and Anita Woelf of the OECD for having provided the ICT investment data. Email: gilbert.cette@banque-france.fr.

2 See Jorgenson (2001), Jorgenson *et al.* (2006), and Byrne *et al.* (2013) for the United States; and Schreyer (2000), Colecchia and Schreyer (2001), Pilat and Lee (2001), van Ark *et al.* (2008), Cette *et al.* (2009), Timmer *et al.* (2011), and Cette and Lopez (2012) for different advanced countries.

In order to provide a long-term perspective, this study covers the 1970–2013 period and focuses on the total economy of each country, not only the business sector. To perform such an analysis, we built an ICT capital stock series with OECD data.

In theory, the contribution of ICT to labour productivity growth passes through two channels. First, the use of ICT as a factor of production increases capital intensity which increases labour productivity. Second, the ICT-producing sector has higher levels of productivity, on average, than other economic sectors; therefore as the relative important of this sector increases, labour productivity increases. Our analysis is linked to the first channel.

Section 1 presents the data and the methodology for evaluating the contribution of ICT to labour productivity growth. Sections 2 and 3 successively describe the diffusion of ICT as a factor of production and show the contribution of these technologies to labour productivity growth. Section 4 concludes.

Data and Methodology

The ICT investment data were provided by the OECD for the total economy for each of the three ICT components (hardware, software, and communications equipment) for the G7 (except Japan), three other large European countries (Spain, Belgium, and the Netherlands), and a Scandinavian country (Finland). A 'Eurozone' is reconstructed by aggregating the data of Germany, Belgium, France, Italy, Spain, the Netherlands, and Finland. These countries represented 84 per cent of GDP in the Eurozone in 2012. The data we used were available for the period from 1960 through 2012 (2011 for the United Kingdom), and after a number of corrections and backward extrapolations, we made the data available for the 1950-2012 period.

The capital stock in volume and value terms is constructed for each of the three ICT components using the perpetual inventory method[3] while assuming a constant annual depreciation rate of 30 per for hardware and software and 15 per cent for communications equipment, as in Cette *et al.* (2009). The total ICT capital stock is calculated, in value and volume, by aggregating the capital stock of each component.

The data on GDP in current prices and the GDP deflator come from Eurostat and the OECD. The investment price indices are built, for each country and ICT component, from the US Bureau of Economic Analysis (BEA) National Account Data. BEA integrates technological advances into ICT prices series via hedonic methods. For the other countries, we assume, as proposed by Schreyer (2000), that the relative price ratio of investment in each of the ICT components to GDP is the same as that of the United States. Country-specific ICT price indices from each country were not used due to the inherent difficulty of making international comparison. Instead, by using the BEA methodology for the calculation of non-US ICT deflators we can make international comparisons and incorporate ICT quality improvements simultaneously. All of the price indices and deflators have a base year of 2005 by convention.

The contribution of ICT capital to labour productivity growth was estimated using a growth accounting approach. This is detailed in Box 1.

3 For each of the three ICT components indexed by j, the capital stock (in value or volume) at the end of year t, $K_{j,t}$, is constructed using the relationship: $K_{j,t} = I_{j,t} + (1\text{-}\delta_j)K_{j,t-1}$ where $I_{j,t}$ corresponds to investment in component j during the year t, and δ_j refers to the constant annual depreciation rate specific to component j.

Box 1

Methodology for Estimating the Contribution of ICT to Labour Productivity Growth

The contribution of ICT to labour productivity growth is estimated for each of the three ICT components by applying the growth accounting methodology suggested by Solow (1957).

For each ICT component (the index is excluded for notational purposes), the contribution of capital to labour productivity growth in year t, noted as CO_t, is estimated through the following relation:

$$CO_t = \alpha_t (\Delta k_{t-1} - \Delta n_t - \Delta h_t)$$

where k_{t-1} corresponds to the capital in place at the end of year $t-1$, n_t refers to total employment in year t, and h_t designates the average annual hours worked per person per year t. The notation of the variables in lower case corresponds to their natural log ($x_t = ln(X_t)$), and the growth rate of a variable is approximated by the variation of its logarithm. The Δ symbol refers to the change of a variable ($\Delta X_t = X_t - X_{t-1}$).

The coefficient $\alpha_{T,t}$ is the Tornquist index of the coefficient α_t:

$$\alpha_{T,t} = (\alpha_t + \alpha_{t-1})/2$$

The coefficient α_t corresponds to the share of capital income (remember that this is calculated for each ICT component) in GDP:

$$\alpha_{T,t} = (C_t K_{t-1})/(PQ_t Q_t)$$

where C_t corresponds to the user cost of capital, K refers to the capital stock in volume, PQ corresponds to the GDP deflator, and Q refers to GDP in volume.

The user cost of capital C is calculated eusing the relationship proposed by Jorgenson (1963):

$$C_t = P_t (i_t + \delta + \Delta p_t)$$

where P corresponds to the investment price of the ICT component, i refers to the nominal interest rate, and δ designates the assumed invariant depreciation rate of the ICT component.

In this study, we used the 10 year government bond interest rates for the nominal interest rate.

The Diffusion of ICT

The diffusion of ICT is proxied by the capital coefficient, defined as the ratio of ICT capital stock to GDP. This indicator can be constructed in value or in volume terms.

Following a balanced growth path, once ICT diffusion reaches maturity, we expect stability in the ICT capital coefficient in value. In the past few decades, we observed a continuous drop in the relative price of ICT which has significantly contributed to a fall in the relative price of investment goods (Table 1). This decrease in price means that the ICT capital coefficient in volume has clearly grown much faster than its expression in value.

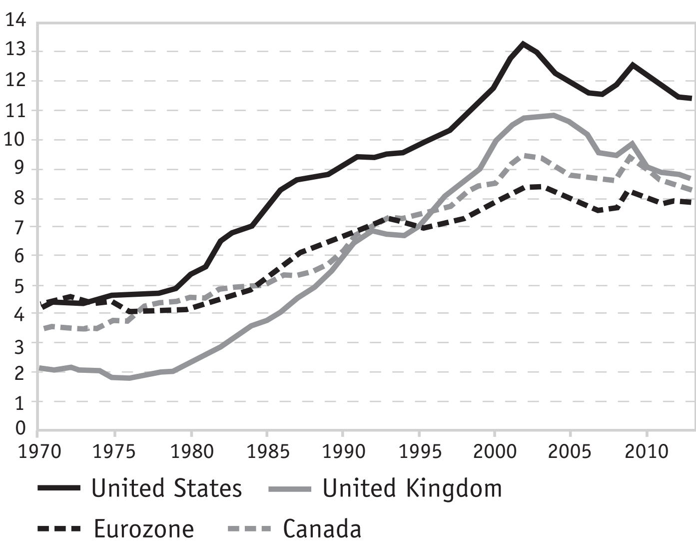
The drop in the relative price of ICT rapidly slows starting in the middle of the 2000s before the beginning of the most recent crisis. This slowdown, which has provoked a still inconclusive debate in the economics literature, receives diverse interpretations (see Cette, 2014, for a summary). One theory, developed by Gordon (2012, 2013), shows how the slowdown in price decreases can result from a gradual exhaustion of Moore's Law due to the slower pace of technological advances in semiconductor chips. In addition to this factor, measurement difficulties in national accounts may also explain this phenomenon (Cette, 2014, Aizcorbe *et al.*, 2008, or Byrne *et al.*, 2013).

Table 1
Trends in the Fixed Investment Prices Relative to the GDP Deflator in the United States, 1959-2012
(average annual rate of change, per cent)

	1959-2012	1959-1974	1974-1995	1995-2004	2004-2012
Non-Residential Fixed Investment	-2.27	-1.85	-1.88	-4.11	-2.02
ICT	-7.16	-6.02	-8.26	-8.95	-4.46
Hardware (Computers)	-18.56	-22.71	-18.45	-19.89	-9.93
Software	-4.23	-4.45	-5.35	-2.72	-2.22
Communication Equipment	-3.33	-0.86	-2.70	-6.52	-5.29

Source: Authors' calculations from BEA original data.

Chart 1
Trends in the ICT Capital Coefficient, 1970-2013
(Ratio of ICT capital stock to GDP in current prices, per cent)



Source: Authors' calculations.

After the rather stable decade of the 1970s, the ICT capital coefficient in value rose in the 1980s and 1990s in the United States, Canada, the Eurozone, and the United Kingdom (Chart 1). This rise implies a growth in ICT diffusion which is linked to an increase in the use of these productive technologies. The ICT coefficient achieved a maximum at the beginning of the 2000s and then stabilized in the Eurozone, decreasing slightly in the United States and Canada, and declining more in the United Kingdom. The peak at the beginning of the 2000s signifies a spurred investment effort associated with the fear of Y2K.

The stability of the nominal ICT capital coefficient since the beginning of the 2000s has already been observed by Cette and Lopez (2012). Our study confirms this result and shows that the stagnation persisted during the crisis. The diffusion of ICT as a factor of production appears to have been stabilized for more than a decade.

The stabilization of the ICT capital coefficient in current prices is at different levels depending on the country. ICT diffusion in the United States settled at a higher level than in the Eurozone, the United Kingdom and Canada. The lag of ICT diffusion is considerable. By 2012, the United States had an ICT capital coefficient that was 30 per cent, 27 per cent, and 25 per cent higher than the Eurozone, Canada, and the United Kingdom, respectively. For Canada, this corresponds to a gap of 40 per cent in ICT investment per worker. Our results are completely consistent with those of Rai and Sharpe (2013).[4] Furthermore, earlier analyses support this hierarchy of ICT diffusion.[5]

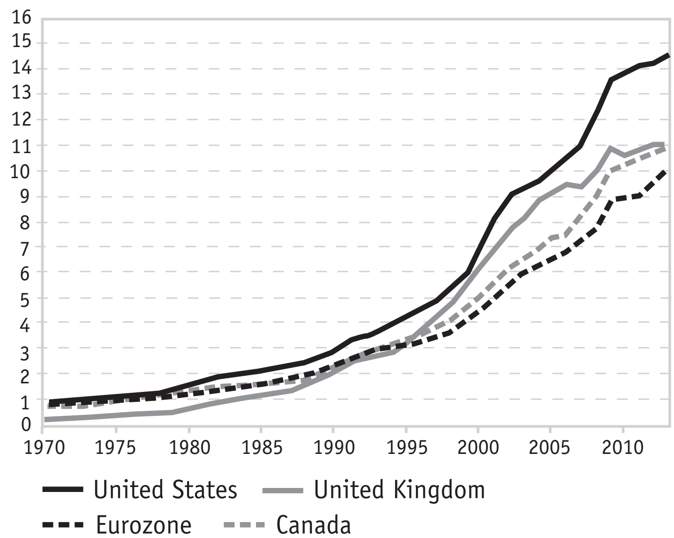
Numerous studies provide explanations for these international differences in ICT diffusion, including the level of post-secondary education among the working age population as well as labour and product market rigidities. For example, an efficient use of ICT requires a higher degree of skilled labour than the use of other technologies. The required reorganization of the firm for effective ICT adoption can be constrained by strict labour market regulations. Moreover, low levels of competitive pressure resulting from product market regulations can reduce the incentive to exploit the most efficient production techniques. A large number of empirical analyses have confirmed the importance of these factors.[6] Quite simply, the United States benefits from the highest level of ICT diffusion because of a higher level of post-secondary education among the working age population and less restrictive product and labour market regulations.

The ICT capital coefficient in volume terms continuously increased over the entire period in all jurisdictions (Chart 2). This indicator follows the same hierarchy of ICT diffusion as the preceding indicator at current prices. By 2012, the United States has the highest diffusion, the Eurozone exhibits the lowest, and Canada and the United Kingdom sit at intermediary positions.

Chart 2

Trends in the ICT Capital Coefficient, 1970-2013

(Ratio of ICT capital stock to GDP in constant 2005 prices, per cent)



Source: Authors' calculations.

A decomposition of the evolution of the ICT capital coefficient in volume terms identifies the contributions of the changes of the ICT capital coefficient in current prices and of relative prices (ICT relative to GDP) to the observed trends.[7] More precisely, this decomposition yields a third component corresponding to cross effects from changes in the ICT capital coefficient in value and the relative prices. The decomposition starts after the first oil shock and covers three sub-periods

4 Rai and Sharpe (2013) demonstrate that the Canada-U.S. ICT investment gap is due to factors which affect software investment and measurement issues.

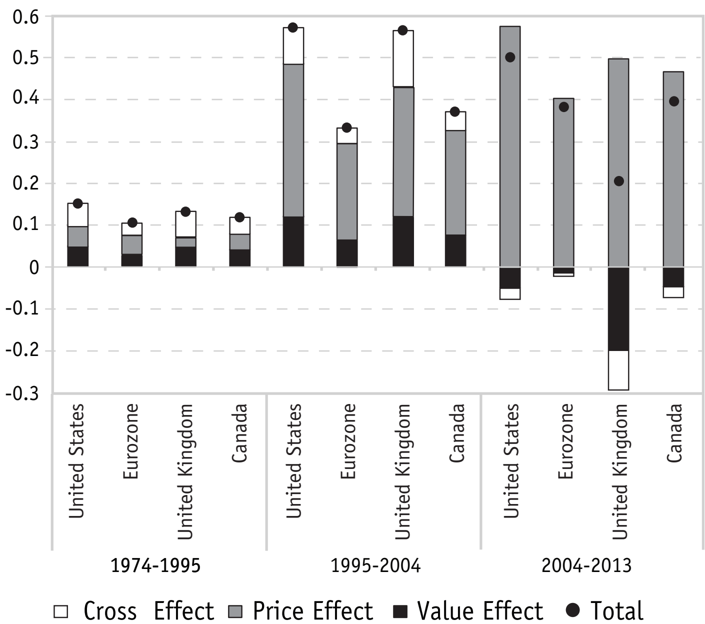
5 See Schreyer (2000), Colecchia and Shreyer (2001), Pilat and Lee (2001), van Ark *et al.* (2008), Timmer *et al.* (2011), and Cette and Lopez (2012).

6 See Aghion *et al.* (2009), Guerrieri *et al.* (2011) and Cette and Lopez (2012) who use country-level panel data, as well as Cette *et al.* (2013) who employ sectoral-level panel data.

7 The ICT capital coefficient in volume is written as K/Q, where K is the volume of ICT capital in place at the end of the period t-1 and Q is the volume of GDP in time t. It is defined by the following relationship: $K/Q = [(PK*K)/(PQ*Q)]*[PQ/PK]$, where PK corresponds to the price of ICT capital in place at the end of the period t-1 and PQ to the price of GDP in year t. The ratio $[(PK*K) / (PQ*Q)]$ corresponds to the ICT capital coefficient in value. Differentiating the preceding equation yields the decomposition formula used to estimate the evolutions of ICT capital in volume:

$$\underbrace{\Delta[K/Q] = [(PK*K)/(PQ*Q)]*\Delta[PQ/PK]}_{\text{Price effect}} + \underbrace{[PQ/PK]*\Delta[(PK*K)/(PQ*Q)]}_{\text{Value effect}} + \underbrace{\Delta[(PK*K)/(PQ*Q)]*\Delta[PQ/PK]}_{\text{Cross effect}}$$

Chart 3
Decomposition of the Evolution of the ICT Capital Coefficient in Volume
(percentage points per year)



Source: Authors' calculations.

which Byrne *et al.* (2013) also use: 1974–1995, 1995–2004 and 2004–2013.

During the 1974–1995 sub-period, each of the three components of the decomposition provides a relatively weak and uniform contribution to the rise in the ICT capital coefficient in constant prices (Chart 3). During the 1995–2004 sub-period, these three contributions are much larger, with the most significant clearly stemming from relative prices. Lastly, during the 2004–2013 sub-period, the contributions from the evolution of the ICT capital coefficient in value and from the cross effects become negligible in the Eurozone and negative in the United States, Canada, and the United Kingdom. The massive contribution from falling relative ICT prices explains the continued growth of ICT capital in volume.

Contribution of ICT Capital to Labour Productivity Growth

The contribution of ICT capital to labour productivity growth, which relates ICT capital to hours (ICT/hours), passes through two channels: first, the use of ICT as a factor of production, via an increase in the ICT capital intensity, and second, the production of the ICT-producing sector, due to a higher level of productivity, on average, than in other sectors. Here, we consider only the former. The estimation of the contribution of ICT to labour productivity growth, of which Box 1 details the methodology, is proposed for the three sub-periods previously mentioned starting after the first oil shock: 1975–1995, 1995–2004, and 2004–2013. It distinguishes the contributions of the three ICT components: hardware, software, and communications equipment.

The 1995–2004 sub-period shows the largest contribution of ICT to labour productivity growth (Chart 4). The literature frequently emphasizes the large increase in the contribution of ICT originating in the middle of the 1990s.[8] The increase is linked to the acceleration of the growth rate of ICT capital in volume which is connected to ICT capital in value and to the relative price of ICT with respect to GDP.

The decrease in the contribution of ICT to labour productivity growth over the last period has been discussed for the United States by Byrne *et al.* (2013). It has also been observed in Canada, the Eurozone, and the United Kingdom (Chart 4). This decline is explained by a slowdown in the growth of the volume of ICT capital which is linked to both the value of ICT capital (due to the slowing pace of ICT investment) and a smaller decrease in the relative price of ICT com-

8 See Jorgenson (2001), Jorgenson *et al.* (2006), or Byrne *et al.* (2013), for the United States, and Cette *et al.* (2009), van Ark *et al.* (2008), or Timmer *et al.* (2011), for different advanced countries.

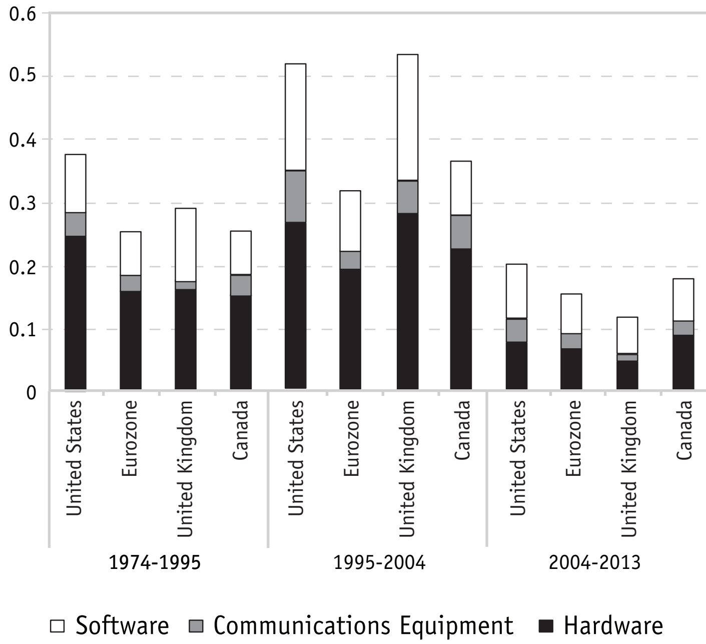
pared to GDP already mentioned above. This smaller decrease may signify, as noted earlier, a gradual exhaustion of the rate of improvements in ICT performance, although such a view is not agreed upon unanimously. Finally, we note that over the three sub-periods, the contribution of the communications equipment component is clearly less than the other two: hardware and software.

Conclusion

Three main results from the preceding analysis are obtained: i) after a long period of sustained growth, ICT capital as a factor of production stabilized in the beginning of the 2000s in the United States, Canada, the Eurozone, and the United Kingdom, and it slightly decreased starting in the middle of the 2000s; ii) this stabilization took place at different levels. It was significantly higher in the United States than in the Eurozone. Canada and the United Kingdom occupy an intermediary level; and iii) in the United States, Canada, the Eurozone, and the United Kingdom, the contribution of ICT to labour productivity growth significantly rose in 1995-2004 relative to 1974-1995. However, the contribution fell in 2004-2013. It only remains positive as a result of continued advances in ICT performance as proxied by falls in the relative price of ICT. These improvements also appear to be sharply decreasing.

These results are new concerning Canada, the Eurozone, and the United Kingdom for the recent period, and raise two questions. The first relates to the potential exhaustion of advances in ICT performance. If this exhaustion materializes in the near future, it could result in the ebb of one of the key sources of productivity growth that took place over the past few decades. As a consequence, this could decrease medium and long term potential growth for the major advanced economies.

Chart 4
Contribution of ICT Capital Intensity to Labour Productivity Growth
(percentage points per year)



Source: Authors' calculations.

The second question relates to the lag in ICT diffusion from which Canada, the Eurozone, and the United Kingdom suffer in comparison with the United States. The literature shows that the lag can be explained, in particular for the Eurozone, by an lower share of workers with post-secondary education and especially by anticompetitive regulations, as well as labour and product market rigidities (Cette and Lopez, 2012). This signifies that ambitious structural reforms could contribute to a reduction of this gap. Consequently, this would allow the Eurozone to benefit from the greater advances in productivity introduced by a stronger diffusion of ICT. In the current period characterized by very weak growth in the Eurozone, this finding strongly suggests the need for a commitment to such ambitious reforms.

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