The Industry and Country Origins of Aggregate Productivity Growth

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Abstract

This paper constructs effective multifactor productivity (MFP) growth for Canada, US, Australia, Japan and EU countries, making use of the EUKLEMS and World IO tables. The effective MFP growth captures the impact of the productivity gains in upstream industries on productivity growth and international competiveness of the domestic industries, and provides a correct measure of productivity growth in the production of final demand products such as consumption, investment and export products. It finds that a significant portion of MFP growth originates from the productivity gains in the production of intermediate inputs in foreign countries, especially for small open economies like Canada. Productivity growth tends to be higher in the production of investment and export products than in the production of consumption products. Technical progress and productivity growth in foreign countries has made a larger contribution to production growth in investment and export products than in consumption products. Finally, the paper provides empirical evidence that is consistent with the hypothesis that effective MFP growth is a more informative indicator of international competitiveness than the standard MFP growth.

1. Introduction

Supply chains of firms and industries have become global in scope as firms and industries take advantage of differences in production costs and technologies across countries. The rise of global production and international production sharing has posed challenges to analyses and measures of countries' competitiveness. The current measures of international competiveness such as gross exports are based on the assumption that all production activities take place in individual economies and have therefore become increasingly less informative for the policy debate. New measures are being developed to inform debates on globalization. For example, Johnson and Noguera (2011) and Koopman et. al. (2012) propose a measure of domestic value-added content of exports. Timmer et. al. (2012a) propose a measure of "global value chain income" that is based on the value-added by countries along the international production chain. Timmer et al. (2012) argue that country's competitiveness and growth depends on its success in capturing a large share of global value chain income and find that there are increasing divergence between gross exports and global value chain incomes for almost all European countries.

With the rise of global supply chains and international production sharing, firms and industries depend on accessing imports of world-class goods and services inputs in order to improve productivity and competitiveness (OECD, 2012).[1] Altomonte and Ottaviano (2011) find that the competitiveness of firms and industries is positively associated with international production sharing and purchases of imported intermediate inputs. The literature on international R&D and technology spillovers since Coe and Helpman (1995) found that foreign

[1] Yakabuski (2013) writes that the success of NAFTA (North American Free Trade Agreement) in 1994) lies in the overwhelming business case for supply-chain integration within North America. Linking our economies makes all three NAFTA countries richer, more competitive and better positioned to conquer global markets.

technical progress contributes to productivity growth and international competiveness of domestic industries through the purchase of intermediate inputs from foreign countries.

However, the current measure of MFP growth fails to capture the impact of productivity gains in the production of intermediate inputs on the productivity gains of domestic industries.[2] This is because the current measure of MFP growth captures only productivity gains originating in a particular industry. On the other hand, an alternate measure (the effective MFP rate), captures the impact of the productivity gains in upstream industries supplying intermediate inputs on the growth and international competiveness of an industry. This paper argues that the effective rate of MFP growth is a more appropriate measure of international competiveness, as it captures the impact of productivity gains originating in a particular domestic industry as well as those in upstream industries (including those abroad) on the growth of the domestic industry.

The effective MFP growth measure was proposed by Domar (1961), Rymes (1971), Hulten (1978), Cas and Rymes (1991), and has been used in a number of studies including those of Durand (1996) and Aulin-Ahmavaara (1999). The measure was developed in a closed economy in those studies. This paper extends those studies to develop an effective MFP growth measure in an open economy when industries and firms source their intermediate inputs both domestically and abroad.

In developing the effective rate of MFP growth, Rymes (1971) and Hulten (1978) argue that the evolution and growth of a sector depends on the effective rate of MFP growth that captures the impact of productivity gains in earlier or upstream stages of production on the final sector, and not just on the productivity gains originating in a particular sector as captured by the standard industry MFP measure.

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[2] The standard measure of industry multifactor growth is constructed as the growth in output that is not accounted for by the growth in capital, labour and intermediate inputs in the industry using the growth accounting framework (see for example, Jorgenson and Griliches 1967, Diewert, 1978).

The effective rate of MFP growth measures the productivity gains of the entire chain that is used to produce goods and services for final use, and takes into account the productivity gains in the production of intermediate inputs purchased both domestically and from abroad. In contrast, the standard MFP measure focuses on industries in isolation and does not capture productivity gains in the production of intermediate inputs used in the production of goods and services for final demand.

The two measures of MFP growth serve different purposes. If one is interested in the efficiencies with which domestic industries uses inputs in production, the proper measure is standard MFP growth. If one is interested in measure of competiveness and growth of industries, the appropriate measure is the effective rate of productivity growth. It is also useful for understanding international competitiveness since it will be shown that the effective rate of productivity growth is more closely related to export growth and product prices.

The paper has a number of objectives.

First, it constructs the effective rate of the productivity growth for the production of final goods and services in Canada, United States, Australia, Japan and EU countries over the period 1995 to 2007. It estimates the effective rate of MFP growth in the production of consumption goods, investment goods, and exports and compares the effective rates of productivity growth in those countries.

Second, the paper decomposes the effective rates of productivity growth into the contributions coming from individual countries and industries. This divides the increase in productivity growth and competitiveness into that which originates from the domestic production process and that which comes from the other countries.[3]

[3] This paper only considers that the impact of productivity gains in the foreign production of intermediate inputs on the productivity growth in the domestic production of final demand products. It does not consider the effect of productivity gains in the production of imported capital on productivity gains in domestic production. Such analysis requires a departure from standard growth accounting framework by treating capital as produced goods as in Cas and Rymes (1991) and Durand (1996). In the standard growth accounting framework, the effect of imported capital is captured through its effect on labour productivity growth from capital deepening.

Third, the paper estimates the correlation between the effective rate of productivity growth and the price of output across industries and compares that with the correlation between standard MFP growth and the product prices across industries. It finds that the effective rate of productivity is a more informative measure of competitiveness compared with standard MFP growth measures.

This paper is related to previous studies on the differences in MFP growth in the production of investment and consumption goods and their implication for economic growth. Oliner and Sichel (2000, 2002) and Oliner, Sichel, and Stiroh (2007) constructed a measure of MFP growth for the production of final demand goods and services in the United States with a focus on the role of production of ICT investment goods. The measure in those papers can be thought as the effective rate of MFP growth for the production of investment goods and other final demand commodities. But their papers assume that the combined input growth is the same for the production of different types of final demand products. This paper shows that a proper measure of effective MFP growth in the production of investment goods and consumption goods needs to take into account the differences in the growth of capital and labour inputs used directly and indirectly in their production.

This paper is also related to the paper by Basu and Fernald (2010) who estimated MFP growth in the production of investment and consumption goods for the United States. Similar to this paper, Basu and Fernald (2002) estimated the MFP growth for the production of investment and consumption goods as the difference in output growth and the growth in combined capital and labour inputs embodied in their production. But their treatment of imports differs from ours. Basu and Fernald (2010) captured the impact of productivity gains through imports on domestic production through the terms of trade. Our treatment of productivity gains through imports follows the traditional of growth accounting framework as developed by Jorgenson and Griliches (1967) and Diewert (1976), among others. The productivity gains in intermediate imports are estimated as the difference between import growth and the combined input growth used for the production of imports in foreign countries.

The effective rate of productivity growth was produced by Statistics Canada in the past. The measure is called the inter-industry productivity growth estimate (Statistics Canada, 1994, Durand, 1996). Gu and Whewell (2005) used that measure to show that the effective MFP growth accelerated in the production of export goods compared with the production of other goods and services subsequent to the Canada-US Free Trade Agreement (CUFTA) that was implemented in 1989 and use this to infer that the CUFTA raised the productivity of Canadian industries exposed to international trade.

The rest of paper is organized as follows. In section 2, the methodology for constructing the effective rate of MFP growth is presented. The construction of this measure requires the world IO tables and the World KLEMS database that were made available as a result of two major international initiatives: World IO and World KLEMS. In section 3, we discuss the data used for empirical analysis. In Section 4, we present our empirical results. This section focuses on the decomposition results and presents empirical evidence that the effective rate of MFP growth is a more informative measure of industry competiveness for Canada. Section 5 concludes the paper.

2. Methodology

The concept of the effective rate of MFP growth was introduced by Hulten (1976) to take into account the fact that the efficiency and competitiveness in the production of products delivered for final demand use (e.g., automobiles) not only depends upon the technological change originating in a particular sector. It also depends on technical progress in the production of intermediate inputs to the sector (e.g., steel, rubber, plastics).

The effective rate of productivity growth measures technical progress in an integrated production processes or production sector for producing final demand output. The concept of an integrated production sector for estimating the effective MFP growth was introduced by Domar (1961). The integrated production sector includes the industry directly involved in the production of the final demand output and all upstream industries that produced intermediate inputs used in the production of final demand output. The output of the integrated production sector is the final demand output delivered to final demand uses such as consumers, businesses, government and exports. The input for the integrated production sector includes not only capital and labour directly employed in production of final goods, but also those employed indirectly in industries that produce its intermediate inputs. Each final demand product is supported by an integrated production sector.

Hulten (1976) shows that the weighted sum of the effective MFP growth rates across final demand sectors is equal to standard MFP growth in the total economy.[4] The weights for the aggregation are estimated as the nominal share of final demand output in total nominal value of final demand and sum to one. This is in contrast to the Domar aggregation of standard MFP growth across industries to derive aggregate MFP growth where weights are estimated as the ratio of industry gross output in total value of final demand and sum up to more than one as part of industry gross output is used as intermediate inputs (Domar, 1961).

While the term of the effective rate of MFP growth was first introduced by Hulten (1976), the distinction between effective rate of MFP growth and standard MFP growth is also apparent in the Domar aggregation of industry MFP growth. Domar (1961) shows that the contribution of an industry to aggregate MFP growth in the production of final demand outputs not only depends on its direct contribution to productivity gains in the production of final demand outputs, but also indirect contribution through productivity gains in the production of intermediate inputs used in other industries for producing final demand products.

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[4] This is only true in a closed economy where the industries only purchase intermediate inputs from other domestic industries, as shown in section 2 of this paper.

For the rest of the section, an example of production process adapted from Domar is used to illustrate the difference between effective MFP growth and standard MFP growth. The effective rate of MFP growth is then presented using the IO production framework. It is shown that the effective rate of MFP growth is more closely related to the competitiveness of industries.

2.1 An Example

The example is taken from Domar (1961). Let an economy consists of two industries. Industry one produces final goods Y_1 using capital K_1, labour L_1, and intermediate inputs M_2. Industry two produces intermediate inputs M_2 for industry one, using capital K_2 and labour L_2. The two industries have the following production function with constant return to scale:

(1) $Y_1 = A_1 F_1(K_1, L_1, M_2),$

(2) $M_2 = A_2 F_2(K_2, L_2).$

The standard MFP growth for the two industries that measures shifts in the production function can be estimated as:

(3) $\Delta \ln A_1 = \Delta \ln Y_1 - (\alpha_1 \Delta \ln K_1 + \beta_1 \Delta \ln L_1 + \gamma_1 \Delta \ln M_2),$

(4) $\Delta \ln A_2 = \Delta \ln M_2 - (\alpha_2 \Delta \ln K_2 + \beta_2 \Delta \ln L_2).$

$\alpha_1, \beta_1 \ \gamma_1 \ \alpha_2 \ \beta_2$ in the two equations are the nominal share of capital, labour and intermediate inputs in the value of total gross output, averaged over two periods.

Substituting (2) into (1) yields a production function for an integrated production process that relates capital inputs and labour inputs to production of final goods. Taking logarithms of the resulting production function for the integrated production process and differentiating with respect to time, we obtain the effective rate of MFP growth for the production of final goods:

(5) $\Delta \ln A = \Delta \ln A_1 + \gamma_1 \Delta \ln A_2.$

The effective rate of MFP growth for a particular integrated production sector is the weighted sum of MFP growth in the two industries that comprise the integrated production sector that processes the final goods, where the weights are the ratio of industry gross output to the value of output of final product. This is the Domar aggregation.

The effective rate of MFP growth shown in equation (5) is the sum of technical process originating in the industry producing the final product and technical progress in the upstream industry producing intermediate input for the final product producing sector. It captures the productivity gains in both industries of the economy for producing the final product. In contrast, the standard MFP growth shown in equations (3) and (4) measures productivity gains that originate in those two industries.

This example was presented in a closed economy and can be extended to an open economy. Suppose the production of intermediate inputs take place in foreign country and the domestic economy consists of one industry that produces final product that purchases the intermediate inputs from the foreign country. The standard estimate of MFP growth is measured using equation (3) while the effective rate of MFP growth is given in equation (5). It is the weighted sum of MFP growth in the domestic production industry and the MFP growth in the foreign production of intermediate inputs. The effective rate of MFP growth exceeds the standard MFP growth by the amount of MFP growth “imported” through the purchase of intermediate inputs.

2.2 Effective Rate of Multifactor Productivity Growth

The effective rate of MFP productivity growth was presented in a simple case of integration in the section above. For a complex case of integration where industries use parts of each other’s outputs as intermediate inputs, the effective rate of MFP growth is a weighted sum of standard MFP growth in all industries involved in the production of final goods where weights are complex function of various substitution elasticities and commodity shares, as shown in

Hulten (1976). To simplify the calculation, Cas and Rymes (1991), Durand (1996), and Aulin-Ahmavaara (1999) assume that the production function can be characterized by Leontief technologies (Leontief,1936 1941). Using the input-output framework, they show that the weights can be derived using the "Leontief inverse".

The effective rate of MFP growth in those studies is developed in a closed economy. In this paper, the measure of effective MFP growth is extended to an open economy to measure the effect of productivity gains in the production of intermediate inputs in other countries on productivity growth and international competiveness of domestic industries. To that end, we extend single country IO tables to a multi-country setting as in Timmer et al. (2012, 2013). The exposition of world IO tables follows closely the setting used in those studies.

Table 1 presents a schematic outline of world input-output table with three regions. A world input-output table is a combination of national input-output tables in which the use of products is broken down according to their origin. For each country, flows of products both for intermediate and final use are split into those produced domestically or those imported.

The rows in the table present the use of output from a particular industry in a country. This can be intermediate use in the country itself (use of domestic output) or by other countries, in which case it is exported. Output can also be for final use, either by the country itself (final use of domestic output) or by other countries, in which case it is exported. The columns present the amounts of intermediate and factor inputs needed for production. The intermediates can be sourced from domestic industries or imported.

The schematic presentation of the world input-output table can be presented in matrix form. We assume that there are S sectors, F production factors and N countries.
Output in each country-sector is produced using domestic production factors and intermediate inputs, which may be sourced domestically or from foreign suppliers. Output may be used to satisfy final demand (either at home or abroad) or used as intermediate input in production

(either at home or abroad as well). Final demand consists of household and government consumption, investment and exports.

Let **x** be the vector of production of dimension (SNx1), which is obtained by stacking output levels in each country-sector. Define **y** as the vector of dimension (SNx1) that is constructed by stacking world final demand for output from each country-sector. We further define a global intermediate input coefficients matrix **A** of dimension (SNxSN):[5]

(6) $$\mathrm{A} = \begin{bmatrix} \mathrm{A}_{11} & \mathrm{A}_{12} \ldots & \mathrm{A}_{1\mathrm{N}} \\ \mathrm{A}_{21} & \mathrm{A}_{22} \ldots & \mathrm{A}_{2\mathrm{N}} \\ \vdots & \vdots & \vdots \\ \mathrm{A}_{\mathrm{N}1} & \mathrm{A}_{\mathrm{N}2} \ldots & \mathrm{A}_{\mathrm{NN}} \end{bmatrix}.$$

The elements or input-output coefficients $a_{ij}(s,t) = m_{ij}(s,t) / x_j(t)$ describe the output from sector *s* in country *I* used as intermediate input by sector *t* in country *j* as a share of output in the latter sector. The matrix **A** describes how the products of each country-sector are produced using a combination of various intermediate products, both domestic and foreign.

A fundamental accounting identity is that total use of output in a row equals total output of the same industry as indicated in the respective column. Using the matrix notation as outlined above, this can be written as:

(7) $$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix} = \begin{bmatrix} \mathrm{A}_{11} & \mathrm{A}_{12} \ldots & \mathrm{A}_{1\mathrm{N}} \\ \mathrm{A}_{21} & \mathrm{A}_{22} \ldots & \mathrm{A}_{2\mathrm{N}} \\ \vdots & \vdots & \vdots \\ \mathrm{A}_{\mathrm{N}1} & \mathrm{A}_{\mathrm{N}2} \ldots & \mathrm{A}_{\mathrm{NN}} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix}.$$

Where x_i represents column vector of dimension S with production levels in country i, and y_i is column vector of dimension S with global final demand for the product of country i. This input-output system can also be written as in a compact form:

(8) $$x = Ax + y.$$

[5] We use lower case letters to denote column vectors and upper case letters to denote matrices.

Rearranging Equation (8), we have the fundamental input-output identify:

(9) $x = (I - A)^{-1} y$.

where **I** is an (SNxSN) identity matrix with ones on the diagonal and zeros elsewhere. $(I - A)^{-1}$ is known as the Leontief inverse (Leontief, 1936). The element in row *m* and column *n* of this matrix gives the total production value of sector *m* needed for production of one unit of final product *n*. The column n of the matrix with dimension SN gives the total production values of S sectors in N countries for the production of one unit of output of final product n.

Let v be the column vector of standard MFP growth based on gross output of dimension (SNx1), and e be the column vector of effective rate of MFP growth of dimension (SNx1) for the production of final product, which are both obtained by stacking MFP growth in each country-sector.

The standard MFP growth is estimated using the growth accounting framework, and is estimated as the difference between output growth and the combined growth of capital, labour and intermediate inputs.

The effective MFP growth for the production of final product n can be calculated as the difference between the difference in the growth in the output of final product and the growth in the combined capital and labour inputs used directly and indirectly in the production of the final product, where the weights are shares of direct and indirect capital and labour costs.

Let z_n be a column vector with the *n*th element representing the value of the global final demand for product n while all the remaining elements are zero. We define $c_i(s)$ as the capital input per unit of gross output produced in sector *s* in country *i* and create the stacked SN-vector **c** containing these 'direct' capital input coefficients. To take 'indirect' contributions into account, we derive the SN-vector of the volume of capital inputs k_n used to produce the output of final product z_n by pre-multiplying the gross outputs needed for production of this final product by the capital input coefficients vector c:

(10) $$k_n = \hat{c}(I - A)^{-1} z_n .$$

in which a hat indicates a diagonal matrix with the elements of **c** on the diagonal.

The calculation method outlined above can be used to estimate the quantity of direct and indirect labour inputs and the costs of direct and indirect labour costs used for the production of a particular final product n.

The effective rate of MFP growth denoted by scalar e_n for the production of the output of final product n is then estimated as:

(11) $$e_n = d \ln z_n - s_{kn}^{'} d \ln k_n - s_{ln}^{'} d \ln l_n ,$$

where the ' symbol denotes the transpose of a vector, i is an SN summation vector of ones, s_{nk} is an SN vector of total capital cost shares in total costs, and s_{nl} is an SN vector of total labour cost shares in total costs.

It can be shown that the effective rate of MFP growth for the production of final product can be estimated as a function of standard MFP growth (Cas and Rymes (1991), Durand (1996), and Aulin-Ahmavaara (1999)):

(12) $$e^{'} = v^{'} (I - A)^{-1}.$$

As discussed above, the column n of the Leontief inverse with dimension SN gives the total production values of S sectors in N countries for the production of one unit of output of final product n. The effective rate of MFP growth for the production of final product n shown in equation (12) is the weighted sum of standard MFP growth of the SN sectors where weights equal to the total production values of S sectors in N countries for the production of one unit of output of final product n. As the sum of value added in the total production is equal to the value of output of the final product (Timmer et al. 2013), the sum of weights used for aggregation in equation (13) exceeds one. This is similar to Domar aggregation (Domar 1961, Jorgenson et al. 2007).

Equation (12) also provides a decomposition of the effective rate of MFP growth into a portion coming from the domestic industries and a portion from foreign industries. The weighted sum of standard MFP growth over all sectors in a region represents the contribution of that region to the effective MFP growth in the production of final product n.

The effective rate of MFP growth for the production of final demand such as investment, consumption, and exports is the weighted sum of the effective rates of MFP growth across industries that produce those final demand products, where the weights for aggregation are estimated as share of industry deliveries to the final demand in the value of the final demand.

It can be shown that the effective rate of MFP growth for the production of total final demand is equal to the standard MFP growth in the aggregate sector in a closed economy. To see that, it is assumed that there is one country (N=1) in the above framework. The effective rate of MFP growth (EMFP) for the production of total final demand is estimated as:

(13) $$EMFP = v^{'}\,(I - A)^{-1}\left(y \Big/ \sum_{s} y_s \right),$$

where $\left(y \Big/ \sum_{s} y_s \right)$ is the column vector of S that gives the share of industry deliveries to the final demand in the value of the final demand. Substituting (9) in equation (13), we have:

(14) $$EMFP = v^{'}\left(x \Big/ \sum_{s} y_s \right).$$

In a closed economy, the value of final demand is equal to the sum of value-added across industries. The term on the right of the equation is the Domar aggregation of standard MFP growth across industries where the weights are given as the ratio of industry gross output to aggregate value-added. As the Domar aggregation of standard MFP growth across industries is equal to standard MFP growth in the total economy, Equation (14) provides a proof that the effective MFP growth for the production of final demand is equal to standard aggregate MFP growth in a closed economy.

In general, the effective MFP growth for the production of final demands will be equal to the standard MFP growth in the total economy if industries source intermediate inputs from domestic industries. It will differ from the standard MFP growth if the domestic industries purchase intermediate inputs from foreign countries and productivity growth differs in the domestic and foreign production of intermediate inputs. The effective rate of MFP growth will be higher than the standard aggregate MFP growth if productivity growth is higher in the foreign production of intermediate inputs. On the other hand, the effective MFP growth will be lower if productivity growth is lower in the foreign production of intermediate inputs.

2.3 Multifactor Productivity Growth and International Competiveness

International competiveness can be defined as the relative output price between two countries (Jorgenson and Nishimizu, 1978, and Ball et. al. 2010). International competitiveness of a domestic industry improves when the output price of the domestic industry relative to that in other countries declines. For MFP growth to be a good indicator of international competiveness, MFP growth should be significantly and negatively correlated with the change in output price.

The standard estimate of MFP growth has been found to be negatively related to the change in output price across industries in the previous empirical studies. For example, Baldwin et al. (2001) found that Canadian industries with relatively high productivity growth rates are also those whose output prices fall relative to the aggregate price deflators. In this paper we argue that the correlation of output price changes with effective MFP growth tends to be stronger than its correlation with standard MFP growth. We interpret this as evidence that the effective MFP growth is a more informative measure of international competitiveness.

To see why this is the case, we make use of the dual approach for measuring productivity growth (for a survey, see Diewert, 1987). According to the dual approach, MFP growth is the difference between changes in input prices and changes in output prices. Alternatively, changes in output price can be written as the difference between changes in input prices and changes in MFP from the dual approach:

(15) $$\Delta \ln p_n = \sum_i s_{n,i} d \ln w_{n,i} - d \ln mfp_n + \varepsilon_n ,$$

where s_i is the cost share of input i, w_i is the price of input, p_n is the output price of industry n, and ε_n is error term.

In general, the correlation between MFP growth and changes in output price is minus one if changes in input prices are uncorrelated with MFP growth across industries. The correlation will be different from minus one if input prices are correlated with MFP growth. The direction of the difference depends on whether the correlation between input prices and MFP growth are positive or negative.[6]

The standard MFP growth can be estimated as the difference in changes in the prices of capital, labour and intermediate inputs and changes in output prices. The strong correlation between the standard MFP growth and output price changes (or the correlation being close to minus one) requires the assumption that all input prices including that of capital, labour and intermediate inputs are invariant to or uncorrelated with MFP growth. This is highly implausible as the price of intermediate inputs tends to be negatively correlated with productivity growth in their production. For example, the price of semiconductors falls dramatically because of rapid technical progress in its production.

The effective MFP growth for the production of a product can be estimated as the difference in changes in the prices of capital and labour inputs used directly and indirectly in its production and changes in the output price. The strong correlation between the standard MFP growth and output price changes (or the correlation being close to minus one) only requires the

[6] This is similar to the bias in coefficient estimates due to omitted variables in the regression. For the discussion, on the omitted variable bias, see Wooldridge (2002).

assumption that the prices of capital and labour inputs are invariant to or uncorrelated with MFP growth. It does not require the assumption that the price of intermediate inputs is invariant to MFP growth. The price of intermediate inputs is allowed to vary with productivity growth, as the effective MFP growth captures the effect of technical change in the production of intermediate inputs.

The discussion suggests that the effective MFP growth should be more closely related to output price change and provides a more informative measure of international competitiveness.

3. Data

We make use of two databases: the World Input-Output Database (WIOD) (Timmer et al., 2012) and EU KLEMS database (O'Mahony and Timmer, 2009).

The world input-output table is an extension of the national input output table which shows the use of products, being for intermediate or final use. The difference with the national table is that the use of products is broken down according to their country origins. For a country, flows of products both for intermediate and for final use are split into domestically produced or imports. In addition, the world input-output table shows in which foreign industry the product is produced. As the information on the split of intermediate inputs and final use between domestically produced and imported is not available in the published national input-output tables, the import proportionality assumption, applying a product's economy-wide import share for three separate use categories (intermediate, investment and consumption) is used to estimate the split for the construction of the world input-output tables.[7]

The world input-output tables cover 35 industries and 6 final demand categories in each of the 40 countries in the world for the period from 1995 to 2009. The WIOD is used to calculate

[7] The import proportionality assumption used in the construction of world input-output tables improves upon the more restrictive proportionality assumption used in previous studies. Those studies apply a product's economy-wide import share for all use categories. As shown in Feenstra and Jensen (2012) and Baldwin et al. (2014), that more restrictive assumption can generate biased estimates.

the Leontief inverse matrix, as well as product expenditure shares within each demand categories (total final demand, consumption, investment and export).

The EUKLEMS provides data on economic growth and productivity for 25 of the 27 EU member states, as well as Australia, Canada, Japan and the U.S. It covers as many as 72 industries from the period 1970 to present. The gross output measure of productivity is used in this paper. In cases where this measure is not available, we derive it by using value-added productivity adjusted by a ratio of value-added to gross output.

The industrial classification used in both the WIOD and the EU KLEMS databases are consistent with the European NACE 2 industry classification. Linking the two industry lists in the two databases yields a final total of 31 industries. Based on the availability of productivity data in the EU KLEMS, we group countries into the following six groups: Canada, the U.S., Australia, Japan, EU, and the rest of the world (ROW). The EU group only includes 10 member countries, where productivity measures are available. The 10 EU countries include Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Spain and United Kingdom. Due to the unavailability of data, the productivity growth for the rest of the world is assumed to be zero. This assumption will not impact on the main results in the study, since trade with the rest of world accounts for a small share of total trade for Canada, the U.S., Australia, Japan and the EU.

4. Empirical Evidence

This section presents the estimates of effective MFP growth in production of final demand products for Canada, the U.S., Australia, Japan and EU Countries over the period 1995 to 2000 and 2000 to 2007. We focus on those two periods as the economic growth post 2000 differed markedly from that of the previous decade in those countries. The 1990s is marked by strong growth in those countries. After 2000, most countries experienced deep recessions.

4.1 Country Origins of Intermediate Inputs

Before presenting the estimate of effective MFP and its decompositions, we first provide some evidence on the extent of global production integration for the selected years 1995, 2000 and 2007 (Table 2). Intermediate inputs account for an average of 45 to 52 percent of gross output across countries over the three years. The imported share of total intermediate inputs varies. Around 23% of total intermediate inputs in Canada are imported from other countries, compared to 9 percent for the United States, 12% for Australia, 7% for Japan, 10% for the EU countries and 13% for the rest of the world. Canada is highly integrated to the upstream industries in the United States, importing from the United States an average of 14% of its total intermediate inputs. There is a global trend toward the integration of production across countries, with developed countries (Canada, the United States, Australia, Japan and EU countries) importing increasingly more intermediates from the rest of the world.

4.2 Standard vs. Effective Multifactor Productivity Growth for the Total Economy

Table 3 compares standard and effective MFP growth estimates in the production of final demand products in a country or region. For Canada, effective MFP growth in the production of final demand products is lower than standard MFP growth in the total economy for the period 1995 to 2000, while it is higher in the period after 2000. The lower effective MFP growth estimate compared with the standard MFP growth estimate before 2000 is due to the fact that Canadian industries source most imported intermediate inputs from the United States and productivity growth in the United States is lower than in Canada over that period. The relatively higher effective MFP growth in Canada after 2000 occurs because productivity growth is higher in the production of intermediate inputs in the U.S. than in Canada.

For the United States, the effective MFP growth estimate is higher than the standard MFP growth estimate because U.S. industries purchase intermediate inputs from other countries including Canada, which tend to have higher productivity growth in the production of intermediate inputs in the pre-2000 period. Post 2000, the effective MFP growth estimate is similar to the standard MFP growth estimate in the United States.

For the EU countries, the two MFP growth measures are similar for the period 1995 to 2000. For the period after 2000, the effective MFP growth is lower than the standard MFP growth.

It should be noted that the estimates of effective MFP growth in this paper may be biased since it is assumed that there is no MFP growth in countries other than those included in this paper (Canada, U.S., Australia, Japan, EU countries). In general, the bias should be negligible when the share of intermediate inputs imported from those other countries is small. But as the share of imported intermediate inputs from those countries become large for countries such as Japan, Australia or EU countries, the bias may become significant.

To examine the size of bias, we re-estimate the effective MFP growth assuming that MFP growth in the rest of world is equal to MFP growth in U.S. industries. The results are presented in table 1 in the appendix. Assuming the rest of world has the same MFP growth as U.S. industries increased the estimate of effective MFP growth by about 0.1 percentage points. In general, the effective MFP growth from this alternative assumption is higher than the standard MFP growth in all countries except in Japan,

4.3 Country Origins of Multifactor Productivity Growth in Total Economy

To see how much a country has benefited from productivity growth from other countries, we decompose effective MFP growth in the production of final products into contributions of countries (Table 4). Within-country productivity gain tends to be the main driver of productivity growth in the production of final demand products. But there are sizeable differences across countries and time periods. For example, between 1995 and 2000, 0.66 percentage points or 75% of 0.87% growth in MFP in Canada originated from productivity growth within the country, while 20% came from productivity growth in the United States. This compared to almost 100% of productivity growth coming from the within–country component in the United States.

The country origins of MFP growth also changed over time for some countries. In Canada, the within-country contribution has declined from 75% in the pre-2000 to 33% in the post-2000 period, while the contribution from MFP growth in the U.S. has increased from 19% to 55%. For the U.S., the within-country contribution accounted for almost all of productivity growth in both periods.

Canada benefited more from productivity gains in the production of intermediate inputs in foreign countries than did the U.S., Australia, Japan and EU countries, as Canada imported a larger share of intermediate inputs from foreign countries than those other countries, and productivity growth in the foreign supplier industries (the United States) is higher.

4.4 Multifactor Productivity Growth by Final Demand Categories

Productivity growth and technical progress for the production of investment and consumption products have been shown to have different economic trajectories over time. For example, Basu and Fernald (2010) found that productivity growth in the production of investment products was found to be negatively related to the growth in hours, investment, consumption and output on the U.S., while productivity growth in the production of consumption products was found to be positively related the growth in those variables.

The difference in MFP growth in production of investment, consumption, and exports is presented in Table 4.[8] Productivity growth tends to be higher in the production of investment and export products than in the production of consumption products.[9] For example, in the United States, MFP growth in the production of consumption, investment and export products was

[8] The effective MFP growth for the production of final demand products is the weighted sum of effective MFP growth across industries using nominal share of industries in total final demand products as weights. The industry shares of final demand products are presented in tables 3 and 4 in the appendix.
[9] Basu and Fernald (2010) found similar results for the United States.

0.8%, 1.9% and 3.2% in the pre-2000 period, and 0.5%, 0.4% and 2.1% in the post-2000 period. This can be attributed to relatively high productivity growth in those industries that produce investment and export products (such as the electrical and optical equipment, transport equipment) compared with slower and even negative productivity growth in the consumption-producing industries (such as real estate activities, public administration and health/social work industries (Appendix Tables 3-4).

The country origins of productivity gains differ across consumption, investment, and export products, as shown in Table 4. In general, technical progress and productivity growth in foreign countries made a larger contribution to production growth in investment and export products than to consumption products, as industries producing investment and exports are more integrated with industries in foreign countries and tend to have higher productivity growth than the industries producing consumption products. For example, technical progress in foreign industries contributed 0.16 percentage points to productivity growth in the production of consumption products in Canada over the period 1995 to 2000, while it contributed 0.46 and 0.37 percentage points to productivity growth in the production of investment and export products.

4.5 Offshoring and Multifactor Productivity Growth

Effective MFP growth differs in the production of goods and services (Tables 5 and 6). For the period 1995 to 2000, the MFP growth in the production of goods was higher than in the production of services in Canada, the U.S., Japan, and EU countries except in Australia, due to large gains in the production of information and communication technologies. For the period after 2000, productivity growth tends to be higher in the production of services in those countries, which is often attributed to the adoption of information and communication technologies (Jorgenson, et al., 2007; van Ark, 2008).

There was an increasing trend toward outsourcing and offshoring in developed countries over the last 20 years due to the decline in communication costs and trade costs (see for example, Baldwin and Gu, 2008 for evidence in Canada). Industries in the developed countries purchase an increased amount of service and material intermediate inputs from other domestic industries and foreign countries. To examine the contribution of offshoring to productivity growth, we further decompose the foreign and domestic components of aggregate productivity growth into a part arising from production gains in service intermediate inputs and a part arising from the production gains in goods intermediate inputs. Overall, the contribution of service and material intermediate imports to aggregate MFP growth is still small, but the contribution of material offshoring tends to be higher than the contribution of service offshoring. For example, in Canada, service offshoring contributed 0.1% per year to MFP growth in goods production over the period 1995 to 2000, while material offshoring contributed 0.2% per year to MFP growth in goods production over that same period.

4.6 Multifactor Productivity Growth by Industries for Canada and United States

This section presents results on MFP growth at the detailed industry level for Canada and the United States. Table 7 presents standard and effective MFP growth for 31 industries for Canada while table 8 presents results for the United States. The list of 31 industries is presented in table 2 in the appendix. In general, effective MFP growth tends to be higher than standard MFP growth at the industry level as the effective MFP growth captures the productivity gains in upstream industries in their production of intermediate inputs.

In tables 7 and 8, the effective MFP growth for Canadian and U.S. industries is also traced to the contribution of domestic and foreign countries. Productivity gains in foreign countries made a larger contribution to effective MFP growth in the manufacturing industries than in non-manufacturing industries. This reflects the higher degree of integration of manufacturing industries into the world economy.

4.7 Productivity Growth and International Competiveness

It can be argued that the effective rate of productivity growth calculated at the industry level is a more appropriate measure of international competitiveness. This is demonstrated in the empirical evidence in De Juan and Febrero (2000) that shows that effective MFP growth is more closely related to changes in output prices across industries for Spain than standard MFP growth.

To examine the relationship between MFP growth and international competiveness, we estimate one regression that expresses changes in gross output prices in industry i over a period t ($\Delta \ln P_{i,t}$) as a function of standard MFP ($v_{i,t}$) and another regression that expresses changes in gross output prices as function of effective productivity growth ($e_{i,t}$):

$$\Delta \ln P_{i,t} = \alpha_0 + \alpha_t + \alpha_1 v_{i,t} , \quad (16)$$

$$\Delta \ln P_{i,t} = \beta_0 + \beta_t + \beta_1 e_{i,t} , \quad (17)$$

where α_t and β_t are period dummies.

The sample for the estimation consists of a pool of 31 industries over two periods 1995 to 2000 and 2000 to 2007. The equation is estimated separately for each country or region.

It is hypothesized that the coefficient β_1 on the effective MFP growth variable will be close to minus one than the coefficient α_1 on the standard MFP growth variable. R squared should be higher for the regression on effective MFP growth.

The results are presented in table 9. The R squared from the regression on effective MFP growth (β_1) is higher than the R squared from the regression on standard MFP growth (α_1) for all countries except for EU countries. For EU countries, the R squared is similar for the two regressions. The biggest improvement in R squared is in the regression for Canada. R squared increased from 0.17 for the regression on standard MFP to 0.32 for the regression on effective MFP.

The evidence on the coefficient estimates on the MFP growth variables for Canada, the US, and Japan is consistent with the hypothesis that effective MFP growth is a more informative indicator of international competiveness. The correlation between effective MFP growth and change in output price is closer to minus one than the correlation between standard MFP growth and change in output price. For example the correlation of output price with effective MFP growth is -0.95 across Canadian industries while its correlation with standard MFP growth is -0.78.

But the results vary across countries. For Australia, the correlation with output price is similar for effective and standard MFP growth rates. For the EU countries, the change in output price is more closely related to the standard MFP growth.

5. Conclusion

With the rise of global supply chains and international production sharing, firms and industries are more dependent on accessing imports of world class goods and services inputs in order to improve productivity and competitiveness. To capture the impact of the productivity gains in upstream industries supplying intermediate inputs on productivity growth and international competiveness in the domestic industries, this paper constructs the effective rate of MFP growth for Canada, US, Australia, Japan and EU countries. It makes use of the EUKLEMS and World IO tables.

In order to measure the competiveness and MFP growth of particular products, analysts require estimates of the effective rate of productivity growth that captures the impact of both productivity gains originating in the production of that product and productivity gains in upstream industries (both domestic and foreign) supplying intermediate material used in the production of the final product. In contrast, the standard estimate of MFP growth measures only productivity gains originating in the final production stage of the product.

A measure of the growth in effective multifactor productivity also provides a correct measure of productivity gains in the production of final demand products such as investment, consumption and export products that can be used to compare efficiency gains across these categories.

The paper finds that a significant portion of MFP growth originates from the productivity gains in the production of intermediate inputs in foreign countries, especially for small open economies like Canada. Canada benefited more from productivity gains in foreign countries than did the U.S., Australia, Japan and EU countries, as Canada imported a larger share of intermediate inputs from foreign countries than other countries studied here, and productivity growth in the foreign supplier industries (the United States) was higher. Foreign contribution of MFP growth in Canada increased from 25% to 67% from the period 1995 to 2000 and 2000 to 2007.

Most of the foreign contribution to productivity growth is from the imports of material inputs (or material offshoring) rather than imports of services intermediate inputs (or service offshoring). This is due to a higher share of material inputs in total intermediate imports and relatively high productivity growth in the production of material inputs.

Productivity growth tends to be higher in the production of investment and export products than in the production of consumption products. In general, technical progress and productivity growth in foreign countries made a larger contribution to production growth in investment and export products than in consumption products, as industries producing investment and exports are more integrated with industries in foreign countries and tend to have higher productivity growth than the industries producing consumption products.

Productivity gains in foreign countries made a larger contribution to effective MFP growth in the manufacturing industries than in non-manufacturing industries, as a result of the more extensive integration of manufacturing industries into the world economy.

The paper provides empirical evidence that is consistent with the hypothesis that effective MFP growth is a more appropriate indicator of international competitiveness than standard estimates of MFP growth since the former is more closely related to the decline in output price across industries.

We note that the effective measure of MFP growth in this paper depends on the quality of underlying industry level data: the industry KLEMS database, the world input/output tables. The improvement of KLEMS database and input/output tables by national statistical agencies, international statistical agencies and international research initiative such World KLEMS (Jorgenson, 2012) and World IO tables (Timmer et al. 2012b) is essential for a better understating of international competitiveness and productivity growth.

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Table 1
Schematic Outline of World Input-Output Table, three regions

	Country A Intermediate Industry	Country B Intermediate Industry	RoW C Intermediate Industry	Country A Final Domestic	Country B Final Domestic	RoW C Final Domestic	Total
Country A Industry	Intermediate use of domestic output	Intermediate use by B of exports from A	Intermediate use by C of exports from A	Final use of domestic output	Final use by B of exports from A	Final use by C of exports from A	Output in A
Country B Industry	Intermediate use by A of exports from B	Intermediate use of domestic output	Intermediate use by C of exports from B	Final use by A of exports from B	Final use of domestic output	Final use by C of exports from B	Output in B
RoW C Industry	Intermediate use by A of exports from Row	Intermediate use by B of exports from RoW	Intermediate use of domestic output	Final use by A of exports from Row	Intermediate use by B of exports from RoW	Final use of domestic output	Output in RoW
	Value added	Value added	Value added				
	Output in A	Output in B	Output in RoW				

Source: Adapted from Timmer et al. (2012).

Table 2
Country Origins of intermediate inputs (in percent)

	Canada	United States	Australi a	Japan	EU	Rest of the world
Share of intermediate inputs in gross output, averaged over 1995, 2000, 2007						
	46	45	51	47	48	52
Imported share of intermediate inputs, averaged over 1995, 2005 and 2007						
	23	9	12	7	10	13
Country origins of intermediate inputs: average country share of total intermediate inputs,1995, 2000, 2007						
Canada	77	2	0	0	0	0
United States	14	91	2	1	2	4
Australia	0	0	88	0	0	0
Japan	1	1	1	93	0	2
EU	3	2	3	1	90	6
Rest of the world	5	5	6	5	8	87
Total	100	100	100	100	100	100
Percentage point changes in the country share of intermediate inputs between 1995 and 2007						
Canada	2	0	0	0	0	0
United States	-4	-3	0	0	0	-1
Australia	0	0	-1	0	0	0
Japan	-1	0	0	-6	0	-1
EU	-1	0	-1	0	-4	0
Rest of the world	3	3	3	5	4	2

Data source: Authors' tabulation from the world input-output database

Table 3
Average annual growth in standard and effective multifactor productivity growth by country for producing final demand products (in percent)

Region	Standard MFP growth	Effective MFP growth
1995-2000		
Canada	0.94	0.87
United States	0.85	1.01
Australia	0.97	0.87
Japan	0.31	0.24
European Union	0.38	0.35
2000-2007		
Canada	-0.04	0.22
United States	0.45	0.47
Australia	-0.53	-0.16
Japan	1.34	1.11
European Union	0.35	0.24

Data source: Authors' tabulation from the world input-output tables and EU-KLEMS

Table 4
Country origins of effective multifactor productivity growth (in percentage points)

	1995 - 2000					2000 - 2007				
	Canada	**U.S.**	**Australia**	**Japan**	**EU**	**Canada**	**U.S.**	**Australia**	**Japan**	**EU**
EMFP growth in the production of final demand product										
Total	**0.87**	**1.01**	**0.87**	**0.24**	**0.35**	**0.22**	**0.47**	**-0.16**	**1.11**	**0.24**
Canada	0.66	0.02	0.00	0.00	0.00	0.07	-0.01	0.00	0.00	0.00
U.S.	0.19	0.98	0.05	0.02	0.04	0.12	0.45	0.03	0.02	0.03
Australia	0.00	0.00	0.79	0.00	0.00	0.00	0.00	-0.23	-0.01	0.00
Japan	0.01	0.01	0.01	0.21	0.01	0.02	0.01	0.02	1.10	0.01
EU	0.02	0.00	0.02	0.00	0.30	0.02	0.01	0.02	0.01	0.21
EMFP growth in the production of consumption products										
Total	**0.60**	**0.78**	**0.89**	**0.11**	**0.38**	**0.20**	**0.47**	**-0.39**	**1.05**	**0.22**
Canada	0.44	0.01	0.00	0.00	0.00	0.08	-0.01	0.00	0.00	0.00
U.S.	0.14	0.76	0.04	0.01	0.03	0.10	0.46	0.03	0.01	0.03
Australia	0.00	0.00	0.82	0.00	0.00	0.00	0.00	-0.45	-0.01	0.00
Japan	0.01	0.01	0.01	0.09	0.01	0.01	0.01	0.02	1.05	0.01
EU	0.01	0.00	0.02	0.00	0.34	0.01	0.01	0.02	0.00	0.19
EMFP growth in the production of investment products										
Total	**1.96**	**1.86**	**0.84**	**0.58**	**0.24**	**0.30**	**0.38**	**0.43**	**1.27**	**0.32**
Canada	1.50	0.03	0.00	0.00	0.00	0.05	0.00	-0.01	0.00	-0.01
U.S.	0.40	1.79	0.07	0.04	0.06	0.20	0.34	0.04	0.03	0.04
Australia	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.35	-0.01	0.00
Japan	0.03	0.02	0.02	0.52	0.01	0.03	0.03	0.02	1.25	0.02
EU	0.03	0.01	0.03	0.01	0.16	0.03	0.02	0.03	0.01	0.27
EMFP growth in the production of export products										
Total	**1.68**	**3.17**	**1.02**	**1.26**	**0.73**	**-0.16**	**2.09**	**-1.25**	**2.48**	**0.78**
Canada	1.31	0.03	0.00	0.00	0.00	-0.42	-0.01	-0.01	0.00	0.00
U.S.	0.33	3.10	0.04	0.07	0.07	0.20	2.05	0.03	0.05	0.05
Australia	0.00	0.00	0.94	0.00	0.00	-0.01	0.00	-1.30	-0.02	0.00
Japan	0.02	0.02	0.01	1.17	0.01	0.03	0.03	0.02	2.43	0.02
EU	0.02	0.01	0.02	0.01	0.64	0.03	0.02	0.02	0.01	0.72

Data source: Authors' tabulation from the world input-output tables and EU-KLEMS

Table 5

Country and industry origins of multifactor productivity growth, 1995 to 2000

	Within the country		Outside the country		
Products	**Within industry**	**Outside industry**	**Within industry**	**Outside industry**	**Total**
Canada					
Goods	1.30	0.19	0.34	0.07	1.90
Services	0.08	0.08	0.02	0.08	0.26
All	0.54	0.12	0.14	0.08	0.87
Goods	1.36	0.39	0.07	0.00	1.82
Services	0.54	0.11	0.00	0.02	0.67
All	0.79	0.19	0.02	0.01	1.01
Goods	0.34	0.38	0.10	0.02	0.83
Services	0.82	0.02	0.01	0.05	0.90
All	0.64	0.16	0.04	0.04	0.87
Japan					
Goods	0.33	0.11	0.05	0.01	0.51
Services	0.03	0.04	0.00	0.01	0.08
All	0.14	0.07	0.02	0.01	0.24
EU					
Goods	0.50	0.03	0.06	0.01	0.60
Services	0.10	0.07	0.00	0.02	0.19
All	0.25	0.05	0.03	0.02	0.35

Data source: Authors' tabulation from the world input-output tables and EU-KLEMS

Table 6

Country and industry origins of multifactor productivity growth, 2000 to 2007

	Within the country		Outside the country		
Products	**Within industry**	**Outside industry**	**Within industry**	**Outside industry**	**Total**
Canada					
Goods	-0.24	0.15	0.21	0.05	0.18
Services	0.20	-0.03	0.02	0.06	0.25
All	0.04	0.04	0.09	0.06	0.22
Goods	0.42	0.22	0.02	0.01	0.68
Services	0.33	0.04	0.00	0.01	0.38
All	0.36	0.09	0.01	0.01	0.47
Goods	0.08	-0.07	0.07	0.02	0.09
Services	-0.31	-0.05	0.01	0.04	-0.32
All	-0.17	-0.06	0.03	0.03	-0.16
Goods	0.96	0.25	0.01	0.01	1.23
Services	0.94	0.10	0.00	0.00	1.04
All	0.95	0.15	0.01	0.00	1.11
Goods	0.43	0.05	0.04	0.01	0.54
Services	0.00	0.05	0.01	0.02	0.08
All	0.16	0.05	0.02	0.02	0.24

Data source: Authors’ tabulation from the world input-output tables and EU-KLEMS

Table 7
Country origin of multifactor productivity growth by industry, Canada

			Country contribution to EMFP							Country contribution to EMFP				
Industry	**MFP**	**EMFP**	**Canada**	**U.S**	**Australia**	**Japan**	**EU**	**MFP**	**EMFP**	**Canada**	**U.S**	**Australia**	**Japan**	**EU**
				1995-2000							2000-2007			
1	1.5	2.3	2.2	0.1	0.0	0.0	0.0	0.8	1.2	1.1	0.1	0.0	0.0	0.0
2	-1.6	-1.4	-1.5	0.1	0.0	0.0	0.0	-3.3	-3.3	-3.4	0.0	0.0	0.0	0.0
3	0.2	1.2	1.0	0.1	0.0	0.0	0.0	0.0	0.5	0.4	0.1	0.0	0.0	0.0
4	1.1	1.8	1.6	0.2	0.0	0.0	0.0	-0.9	-0.6	-0.8	0.2	0.0	0.0	0.0
5	1.5	2.8	2.6	0.1	0.0	0.0	0.0	1.3	2.0	1.9	0.1	0.0	0.0	0.0
6	1.2	1.9	1.8	0.1	0.0	0.0	0.0	0.2	0.6	0.5	0.1	0.0	0.0	0.0
7	0.1	-0.2	-0.2	0.0	0.0	0.0	0.0	-0.6	-2.0	-2.0	0.0	0.0	0.0	0.0
8	1.4	1.8	1.8	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	0.1	0.0	0.0	0.0
9	1.3	1.9	1.8	0.1	0.0	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0
10	1.8	2.3	2.2	0.1	0.0	0.0	0.0	0.7	0.7	0.7	0.0	0.0	0.0	0.0
11	1.3	2.1	1.9	0.2	0.0	0.0	0.0	0.4	0.4	0.5	-0.1	0.0	0.0	0.0
12	1.0	2.1	1.5	0.5	0.0	0.0	0.0	0.3	0.9	0.5	0.3	0.0	0.0	0.0
13	2.8	4.8	3.2	1.4	0.0	0.1	0.1	-1.5	-0.6	-1.4	0.6	0.0	0.1	0.1
14	0.9	2.0	1.4	0.5	0.0	0.0	0.0	-0.1	0.7	0.0	0.5	0.0	0.1	0.1
15	2.7	3.6	3.3	0.2	0.0	0.0	0.0	-0.3	0.2	0.0	0.2	0.0	0.0	0.0
16	0.3	0.4	0.4	0.0	0.0	0.0	0.0	0.6	0.4	0.4	0.0	0.0	0.0	0.0
17	0.9	1.6	1.3	0.3	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0
18	0.0	0.2	0.1	0.0	0.0	0.0	0.0	1.9	2.0	2.0	0.0	0.0	0.0	0.0
19	1.4	2.0	1.7	0.3	0.0	0.0	0.0	1.3	1.6	1.4	0.2	0.0	0.0	0.0
20	2.0	2.1	2.1	0.0	0.0	0.0	0.0	0.9	1.0	1.0	0.0	0.0	0.0	0.0
21	0.5	0.8	0.8	0.1	0.0	0.0	0.0	-0.1	0.1	0.1	0.0	0.0	0.0	0.0
22	-0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0
23	0.8	1.0	0.9	0.0	0.0	0.0	0.0	2.4	2.5	2.5	0.0	0.0	0.0	0.0
24	-1.4	-1.3	-1.4	0.1	0.0	0.0	0.0	0.1	0.3	0.2	0.0	0.0	0.0	0.0
25	0.1	0.2	0.2	0.0	0.0	0.0	0.0	-0.3	-0.2	-0.2	0.0	0.0	0.0	0.0
26	0.5	0.8	0.8	0.1	0.0	0.0	0.0	-0.2	0.1	0.0	0.1	0.0	0.0	0.0
27	0.2	0.5	0.4	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0
28	-0.5	-0.4	-0.4	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.0
29	-0.4	-0.1	-0.3	0.2	0.0	0.0	0.0	-0.6	-0.3	-0.5	0.1	0.0	0.0	0.0
30	-0.5	-0.2	-0.4	0.1	0.0	0.0	0.0	-0.3	-0.1	-0.2	0.1	0.0	0.0	0.0
31	6.2	6.2	6.2	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0	0.0	0.0	0.0

Data source: Authors' tabulation from the world input-output tables and EU-KLEMS
Note: MFP and EMFP stands for standard and effective multifactor productivity growth respectively

Table 8
Country origin of multifactor productivity growth by industry, the United States

			Country contribution to EMFP							Country contribution to EMFP				
Industry	MFP	EMFP	Canada	U.S	Australia	Japan	EU	MFP	EMFP	Canada	U.S	Australia	Japan	EU
			1995-2000							2000-2007				
1	1.8	2.7	0.0	2.7	0.0	0.0	0.0	0.6	1.0	0.0	1.0	0.0	0.0	0.0
2	-2.0	-1.9	0.0	-1.9	0.0	0.0	0.0	-2.3	-2.3	0.0	-2.3	0.0	0.0	0.0
3	-0.7	0.4	0.0	0.3	0.0	0.0	0.0	-0.6	-0.2	0.0	-0.2	0.0	0.0	0.0
4	0.9	1.9	0.0	1.8	0.0	0.0	0.0	1.3	2.1	0.0	2.0	0.0	0.0	0.0
5	-0.1	1.0	0.1	0.9	0.0	0.0	0.0	0.7	1.4	0.0	1.3	0.0	0.0	0.0
6	-0.3	0.3	0.0	0.2	0.0	0.0	0.0	0.1	0.6	0.0	0.5	0.0	0.0	0.0
7	0.0	-0.5	0.0	-0.4	0.0	0.0	0.0	0.1	-0.7	-0.2	-0.6	0.0	0.0	0.0
8	-0.9	-0.4	0.0	-0.5	0.0	0.0	0.0	0.4	0.7	0.0	0.7	0.0	0.0	0.0
9	1.0	1.7	0.0	1.6	0.0	0.0	0.0	0.1	0.6	0.0	0.6	0.0	0.0	0.0
10	0.4	0.8	0.0	0.8	0.0	0.0	0.0	-0.5	-0.4	0.0	-0.4	0.0	0.0	0.0
11	0.7	1.7	0.0	1.6	0.0	0.0	0.0	-0.8	-0.7	0.0	-0.7	0.0	0.0	0.0
12	-0.8	0.6	0.0	0.5	0.0	0.0	0.0	1.1	1.7	0.0	1.6	0.0	0.0	0.0
13	9.2	11.5	0.0	11.4	0.0	0.1	0.0	6.7	7.8	0.0	7.7	0.0	0.1	0.0
14	0.1	1.6	0.1	1.5	0.0	0.0	0.0	1.1	2.0	0.0	1.9	0.0	0.1	0.0
15	2.4	3.4	0.1	3.3	0.0	0.0	0.0	1.9	2.4	0.0	2.3	0.0	0.0	0.0
16	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
17	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	-2.5	-2.2	0.0	-2.2	0.0	0.0	0.0
18	0.8	1.4	0.0	1.4	0.0	0.0	0.0	-0.8	-0.4	0.0	-0.5	0.0	0.0	0.0
19	5.0	5.2	0.0	5.2	0.0	0.0	0.0	1.4	1.6	0.0	1.6	0.0	0.0	0.0
20	3.1	3.3	0.0	3.3	0.0	0.0	0.0	0.6	0.8	0.0	0.8	0.0	0.0	0.0
21	0.4	0.8	0.0	0.8	0.0	0.0	0.0	0.4	0.6	0.0	0.6	0.0	0.0	0.0
22	0.1	0.3	0.0	0.3	0.0	0.0	0.0	0.9	1.2	0.0	1.2	0.0	0.0	0.0
23	-0.7	-0.5	0.0	-0.5	0.0	0.0	0.0	2.8	3.3	0.0	3.3	0.0	0.0	0.0
24	1.2	1.6	0.0	1.6	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0
25	0.1	0.2	0.0	0.2	0.0	0.0	0.0	0.6	0.6	0.0	0.6	0.0	0.0	0.0
26	-0.9	-0.8	0.0	-0.8	0.0	0.0	0.0	0.1	0.4	0.0	0.3	0.0	0.0	0.0
27	-0.4	-0.1	0.0	-0.1	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0
28	-0.8	-0.6	0.0	-0.6	0.0	0.0	0.0	-1.0	-0.8	0.0	-0.8	0.0	0.0	0.0
29	-1.1	-0.7	0.0	-0.7	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
30	-0.6	-0.5	0.0	-0.5	0.0	0.0	0.0	-0.7	-0.5	0.0	-0.5	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Data source: Authors' tabulation from the world input-output tables and EU-KLEMS
Note: MFP and EMFP stands for standard and effective multifactor productivity growth respectively

Table 9
Explanation of changes in output prices by standard vs. effective productivity growth measures

	Canada	U.S.	Australia	Japan	EU
α_1	-0.78 *	-1.20*	-1.20*	-1.25*	-0.90*
β_1	-0.95 *	-1.13*	-1.21*	-1.09*	-0.77*
$R^2_{\alpha_1}$	0.17	0.66	0.31	0.43	0.26
$R^2_{\beta_1}$	0.32	0.74	0.33	0.46	0.25
t-stat α_1	-3.49	-9.78	-3.67	-6.38	-4.11
t-stat β_1	-5.29	-12.31	-4.07	-6.77	-4.07
N_{α_1}	62	60	60	60	60
N_{β_1}	62	62	62	60	62

Appendix Table 1
Average annual growth in standard and effective MFP growth by country for producing final demand products (in percent): assuming the MFP for the rest of the world equals that for the U.S.

Region	Standard MFP growth	Effective MFP growth
1995-2000		
Canada	0.94	0.98
United States	0.85	1.10
Australia	0.97	0.98
Japan	0.31	0.27
European Union	0.38	0.44
2000-2007		
Canada	-0.04	0.35
United States	0.45	0.57
Australia	-0.53	-0.04
Japan	1.34	1.15
European Union	0.35	0.36

Data source: Authors' tabulation from the world input-output tables and EU-KLEMS

Appendix Table 2
List of industries

Industry	WIOT_INDCODE	WIOT_INDNAME
1	AtB	AGRICULTURE, HUNTING, FORESTRY AND FISHING
2	C	MINING AND QUARRYING
3	15t16	FOOD PRODUCTS, BEVERAGES AND TOBACCO
4	17t19	TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR
5	20	WOOD AND PRODUCTS OF WOOD AND CORK
6	21t22	PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING
7	23	Coke, refined petroleum products and nuclear fuel
8	24	Chemicals and chemical products
9	25	Rubber and plastics products
10	26	OTHER NON-METALLIC MINERAL PRODUCTS
11	27t28	BASIC METALS AND FABRICATED METAL PRODUCTS
12	29	MACHINERY, NEC
13	30t33	ELECTRICAL AND OPTICAL EQUIPMENT
14	34t35	TRANSPORT EQUIPMENT
15	36t37	MANUFACTURING NEC; RECYCLING
16	E	ELECTRICITY, GAS AND WATER SUPPLY
17	F	CONSTRUCTION
18	50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
19	51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
20	52	Retail trade, except of motor vehicles and motorcycles; repair of household goods
21	H	HOTELS AND RESTAURANTS
22	60t63	TRANSPORT AND STORAGE
23	64	POST AND TELECOMMUNICATIONS
24	J	FINANCIAL INTERMEDIATION
25	70	Real estate activities
26	71t74	Renting of m&e and other business activities
27	L	PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY
28	M	EDUCATION
29	N	HEALTH AND SOCIAL WORK
30	O	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES
31	P	PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS

Data source: author's aggregation linking World input-output tables and EU-KLEMS

Appendix Table 3
EMFP growth and expenditure shares by industry, Canada

Industry	EMFP growth	Share of imported intermediates in gross output	Expenditure share by industry: Total final demand	Consump-tion	Invest-ment	Export	EMFP	Share of imported intermediates in gross output	Expenditure share by industry: Total final demand	Consump-tion	Invest-ment	Export
			1995 – 2000						**2000 - 2007**			
1	2.30	0.06	0.01	0.01	0.00	0.03	1.21	0.07	0.01	0.01	0.00	0.03
2	-1.37	0.04	0.01	0.01	0.00	0.10	-3.30	0.03	0.01	0.01	0.00	0.14
3	1.19	0.06	0.05	0.07	0.00	0.04	0.49	0.07	0.05	0.06	0.00	0.04
4	1.82	0.14	0.02	0.02	0.00	0.02	-0.60	0.17	0.01	0.02	0.00	0.02
5	2.79	0.04	0.00	0.00	0.00	0.04	2.00	0.05	0.00	0.00	0.00	0.03
6	1.90	0.08	0.01	0.01	0.01	0.08	0.60	0.09	0.01	0.01	0.01	0.05
7	-0.17	0.23	0.01	0.01	0.00	0.02	-2.00	0.21	0.01	0.02	0.00	0.03
8	1.84	0.12	0.01	0.01	0.00	0.05	0.10	0.16	0.01	0.01	0.00	0.05
9	1.94	0.15	0.00	0.00	0.00	0.03	0.32	0.18	0.00	0.00	0.00	0.03
10	2.34	0.10	0.00	0.00	0.00	0.01	0.69	0.09	0.00	0.00	0.00	0.01
11	2.08	0.15	0.01	0.00	0.02	0.08	0.39	0.21	0.01	0.00	0.02	0.09
12	2.11	0.15	0.03	0.01	0.09	0.03	0.85	0.17	0.02	0.01	0.08	0.04
13	4.78	0.25	0.03	0.02	0.10	0.08	-0.61	0.24	0.03	0.01	0.08	0.07
14	1.97	0.26	0.05	0.04	0.08	0.24	0.71	0.31	0.05	0.04	0.08	0.21
15	3.56	0.13	0.01	0.01	0.02	0.03	0.16	0.14	0.01	0.01	0.02	0.03
16	0.40	0.03	0.02	0.02	0.00	0.01	0.45	0.04	0.01	0.02	0.00	0.01
17	1.60	0.11	0.11	0.00	0.55	0.00	0.23	0.11	0.12	0.00	0.56	0.00
18	0.18	0.02	0.00	0.00	0.00	0.00	2.00	0.02	0.00	0.00	0.00	0.00
19	2.05	0.10	0.02	0.02	0.02	0.00	1.64	0.10	0.03	0.02	0.03	0.00
20	2.14	0.03	0.04	0.04	0.02	0.01	0.99	0.03	0.04	0.04	0.03	0.01
21	0.84	0.03	0.04	0.05	0.00	0.02	0.13	0.04	0.04	0.05	0.00	0.02
22	0.10	0.05	0.03	0.03	0.01	0.03	0.12	0.05	0.03	0.03	0.01	0.03
23	0.99	0.02	0.01	0.02	0.00	0.00	2.53	0.02	0.01	0.02	0.00	0.00
24	-1.30	0.03	0.07	0.08	0.02	0.01	0.27	0.03	0.07	0.09	0.02	0.01
25	0.21	0.01	0.10	0.13	0.02	0.01	-0.22	0.01	0.09	0.12	0.02	0.01
26	0.84	0.03	0.01	0.01	0.02	0.03	0.09	0.03	0.02	0.01	0.03	0.03
27	0.49	0.04	0.14	0.17	0.00	0.00	0.24	0.04	0.13	0.17	0.00	0.00
28	-0.36	0.01	0.06	0.08	0.00	0.00	0.26	0.01	0.06	0.07	0.00	0.00
29	-0.07	0.03	0.05	0.06	0.00	0.00	-0.30	0.04	0.05	0.07	0.00	0.00
30	-0.19	0.07	0.04	0.05	0.00	0.01	-0.08	0.09	0.05	0.06	0.00	0.01
31	6.23	0.00	0.00	0.00	0.00	0.00	-0.27	0.00	0.00	0.00	0.00	0.00

Data source: WIOD and EU-KLEMS

Appendix Table 4
EMFP growth and expenditure shares by industry, the United States

Industry	EMFP growth	Share of imported intermediates in gross output	Expenditure share by industry: Total final demand	Consump-tion	Invest-ment	Export	EMFP	Share of imported intermediates in gross output	Expenditure share by industry: Total final demand	Consump-tion	Invest-ment	Export
			1995 – 2000						2000 - 2007			
1	2.73	0.03	0.00	0.01	0.00	0.03	0.97	0.04	0.00	0.01	0.00	0.02
2	-1.86	0.04	0.00	0.00	0.01	0.01	-2.28	0.06	0.01	0.00	0.03	0.01
3	0.36	0.05	0.04	0.04	0.00	0.04	-0.15	0.05	0.03	0.04	0.00	0.03
4	1.90	0.06	0.02	0.02	0.00	0.02	2.05	0.07	0.01	0.01	0.00	0.01
5	1.04	0.04	0.00	0.00	0.01	0.01	1.41	0.04	0.00	0.00	0.00	0.00
6	0.26	0.05	0.01	0.01	0.02	0.03	0.57	0.06	0.01	0.01	0.02	0.03
7	-0.47	0.27	0.01	0.01	0.00	0.01	-0.72	0.32	0.01	0.01	0.00	0.02
8	-0.44	0.07	0.01	0.01	0.00	0.07	0.75	0.09	0.01	0.02	0.00	0.07
9	1.69	0.07	0.00	0.00	0.00	0.02	0.62	0.09	0.00	0.00	0.00	0.02
10	0.84	0.05	0.00	0.00	0.00	0.01	-0.36	0.05	0.00	0.00	0.00	0.01
11	1.68	0.08	0.00	0.00	0.01	0.04	-0.70	0.10	0.00	0.00	0.01	0.04
12	0.61	0.09	0.02	0.00	0.08	0.08	1.70	0.11	0.02	0.00	0.07	0.08
13	11.54	0.11	0.03	0.01	0.11	0.18	7.77	0.12	0.03	0.01	0.10	0.16
14	1.59	0.10	0.04	0.02	0.11	0.12	2.00	0.13	0.04	0.02	0.10	0.13
15	3.39	0.07	0.01	0.01	0.02	0.02	2.36	0.08	0.01	0.01	0.02	0.02
16	-0.06	0.06	0.01	0.02	0.00	0.00	-0.14	0.11	0.01	0.02	0.00	0.00
17	0.03	0.05	0.08	0.00	0.43	0.00	-2.15	0.06	0.08	0.00	0.43	0.00
18	1.45	0.04	0.01	0.02	0.00	0.00	-0.42	0.04	0.01	0.02	0.00	0.00
19	5.22	0.01	0.04	0.03	0.05	0.10	1.58	0.02	0.04	0.03	0.04	0.10
20	3.31	0.02	0.08	0.10	0.02	0.00	0.76	0.02	0.08	0.09	0.02	0.00
21	0.80	0.02	0.04	0.05	0.00	0.00	0.58	0.03	0.04	0.05	0.00	0.00
22	0.26	0.02	0.02	0.02	0.01	0.07	1.18	0.03	0.02	0.02	0.01	0.07
23	-0.48	0.02	0.02	0.02	0.00	0.01	3.29	0.02	0.02	0.02	0.00	0.01
24	1.58	0.01	0.05	0.07	0.00	0.06	0.23	0.02	0.06	0.07	0.00	0.07
25	0.19	0.01	0.10	0.12	0.03	0.00	0.63	0.01	0.10	0.12	0.03	0.00
26	-0.76	0.02	0.03	0.02	0.09	0.06	0.35	0.02	0.04	0.02	0.10	0.07
27	-0.10	0.06	0.17	0.21	0.00	0.01	-0.03	0.08	0.17	0.21	0.00	0.01
28	-0.60	0.00	0.01	0.01	0.00	0.00	-0.80	0.00	0.01	0.01	0.00	0.00
29	-0.72	0.01	0.09	0.12	0.00	0.00	0.03	0.01	0.10	0.12	0.00	0.00
30	-0.46	0.01	0.04	0.05	0.00	0.01	-0.52	0.02	0.04	0.05	0.00	0.01
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Data source: WIOD and EU-KLEMS