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PRODUCTIVITY GROWTH AND INTERNATIONAL COMPETITIVENESS

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This paper presents a measure of effective multifactor productivity (MFP) growth for Canada, the U.S., Australia, Japan and selected EU countries. The measure differs from the standard MFP growth as it measures productivity growth in the production of different types of products instead of by industry and it captures the effect of productivity gains in both foreign and domestic upstream industries. The paper finds that the increase in effective MFP is closely associated with the decline in output price and improvement in international competitiveness. Multifactor productivity growth for small, open economies and for the production of manufacturing, investment and export goods is partly attributable to productivity gains in the production of intermediate inputs in foreign countries.

JEL Codes: O4, F1, F6

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1. INTRODUCTION

As firms and industries take advantage of differences in production costs and technologies across countries, their supply chains have become global. Increasingly, firms and industries depend on accessing imports of goods and services to improve their productivity and competitiveness (OECD, 2012). The international production-sharing and purchases of imported intermediate inputs is found to be an important contributor to improvements in the competitiveness through their effect on productivity growth (Altomonte and Ottaviano, 2011). The empirical studies on global value chains find that goods exports often have large services contents, and therefore improving productivity in upstream service industries can improve the competitiveness of goods exports (Timmer *et al*., 2012a; van Ark *et al*., 2013; Ahmad and Ribarsky, 2014).

However, the traditional growth accounting framework and the standard measure of multifactor productivity (MFP) growth fail to capture the impact that productivity gains in upstream industries have on productivity gains in downstream industries.[1] The standard measure of industry multifactor growth is constructed as the growth in gross output that is not accounted for by the growth in

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[1]In general, the term productivity can mean either partial productivity or multifactor productivity. In this paper, the terms multifactor productivity and productivity are used synonymously.

capital, labor and intermediate inputs in the industry (see for example, Jorgenson and Griliches, 1967; Diewert 1976). It measures the efficiency with which industries use inputs in their production and considers those industries in isolation.

In contrast to the standard MFP growth, the effective MFP growth measures productivity growth in the production of different types of products instead of by industry and it captures that impact of upstream industries. It is constructed as the difference in the growth in gross output that is not accounted by the growth in total capital and labor inputs used directly in the final industry sector and indirectly in the upstream industries supplying intermediate inputs. The effective rate of MFP growth was proposed by Domar (1961), Rymes (1971, 1972), Hulten (1978), Cas and Rymes (1991), and has been used in a number of studies (Durand 1996; Aulin-Ahmavaara 1999).[2] However, in those studies, the measure was developed in a closed economy. This paper extends that work to develop an effective MFP growth measure in an open economy, in which industries and firms source their intermediate inputs both domestically and abroad.

Rymes (1971) and Hulten (1978) contend that the evolution and growth of a sector are affected by the effective rate of MFP growth, which captures the impact of productivity gains in earlier or upstream stages of production on the final sector, rather than just the gains originating in a particular sector as captured by the standard MFP measure.

The effective rate of MFP growth is also useful for understanding international competitiveness. The concept of international competitiveness is often used to analyse the export performance of a country compared with its trading partners. It can be affected by a number of factors including product specialization, product quality, brand names and the after-sales services. For the discussion in this paper, the concept of international competitiveness is restricted to the notion of international price or cost differentials (Jorgenson and Nishimizu, 1978; Durand and Giorno, 1987). International competitiveness of industries and firms is said to improve if the price of their products decline compared with the price of their trading partners. In general, the relative price competitiveness is affected by both relative input price differences and relative MFP growth differences. The paper argues that the increase in effective MFP measure is more closely associated with the decline in output price and changes in price competitiveness than the standard MFP measure as the effective MFP growth captures the impact of productivity gains in upstream industries on changes in output price.[3]

This paper first presents a framework for estimating effective MFP growth in an open economy and then uses that framework to address the following issues:

First, what are the multifactor productivity growth rates in the production of consumption goods and investment goods? The relative growth rates of multifactor productivity in the production of investment and consumption have

[2]The term "effective" is first used by Hulten (1978) to point out the analogy with effective tax incidence. Analogous to the effective tax incidence that measures the final impact of taxes on consumers and producers, the effective MFP growth measures the overall impact of productivity growth in various industries of an economy on an individual industry.

[3]The effective MFP growth can be thought of as measuring productivity growth in the production of a product while standard MFP growth measuring productivity growth in the production of an industry.

implications for long-term growth and the business cycles (Basu *et al.*, 2013). A number of previous studies have estimated the relative MFP growth rates in the production of investment and consumption goods and examined their implications for long-term growth and the business cycle. An appropriate framework for such analysis is the effective MFP measure developed in this paper.

Second, what is the impact of productivity growth in upstream domestic and foreign industries on productivity growth of downstream industries? It has been recognized that an improvement in productivity in the service sectors contributes to productivity growth and international competitiveness of the goods sector. More recent studies on global production have focused on the effect that outsourcing and offshoring have on productivity growth. The effective MFP growth measure in this paper provides a framework for answering those questions[4].

This paper is related to previous studies on MFP growth differences in the production of investment and consumption goods and their implications for economic growth (Oliner *et al.*, 2007, and Basu *et al.*, 2013). Oliner *et al.* (2007) constructed a measure of MFP growth for the production of final demand goods and services in the U.S., with a focus on the role of production of ICT investment goods. The measure in those papers can be thought of as the effective rate of MFP growth for the production of investment goods and other final demand commodities. However, those papers assume that combined input growth is the same for the production of different types of final demand products. By contrast, the present study shows that a measure of effective MFP growth in the production of investment goods and consumption goods must account for differences in the growth of capital and labor inputs used directly and indirectly in their production.

Basu *et al.* (2013) estimated MFP growth in the production of investment and consumption goods for the U.S. Similar to this paper, Basu *et al.* (2013) estimated MFP growth for the production of investment and consumption goods as the difference in output growth and the growth in combined capital and labor inputs embodied in their production. However, they captured the impact of productivity gains from imports on domestic production through the terms of trade. By contrast, in this analysis, the treatment of productivity gains from imports follows the growth accounting framework (Jorgenson and Griliches, 1967; Diewert, 1976); productivity gains in intermediate imports are calculated as the difference between import growth and the combined input growth used in foreign countries to produce the imports.

In the past, Statistics Canada has calculated the effective rate of multifactor productivity growth using a measure called the inter-industry multifactor productivity growth estimate (Statistics Canada, 1994; Durand, 1996). Based on that measure, Gu and Whewell (2005) showed that after implementation of the Canada-U.S. Free Trade Agreement (CUFTA) in 1989, effective MFP growth accelerated in the production of export goods, compared with the production of other goods and services, and thus, inferred that the CUFTA raised the productivity of Canadian industries exposed to international trade.

[4]In general, offshoring will also affect the price competitiveness through its effect on the relative levels of input costs. That effect could be important when industries in the developed countries purchase intermediate inputs from the developing countries with lower production costs. However, this paper will focus on the effect of offshoring on changes in MFP.

The rest of the paper is organized as follows. Section 2 presents the methodology for constructing the effective rate of MFP growth. This requires the world input-output (IO) tables and the EU KLEMS database on industry productivity growth for the EU member states, as well as for Australia, Canada, Japan, and the U.S. (O'Mahony and Timmer, 2009; Timmer *et al.*, 2012b). Section 3 describes the data used for empirical analysis. Section 4 presents empirical results. Section 5 concludes the paper.

2. Methodology

Introduced by Hulten (1978), the concept of the effective rate of MFP growth accounts for the fact that efficiency and competitiveness in producing final demand products (for instance, automobiles) depend not only on productivity growth originating in a particular sector, but also on productivity growth in the production of intermediate inputs to the sector (such as steel, rubber and plastics).

The effective rate of multifactor productivity growth measures technical progress in the production of final demand products which encompasses integrated production processes (Domar, 1961). This includes the industry directly involved in producing the final demand output and all upstream industries producing 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 inputs for the integrated production sector are total capital and labor inputs that include not only capital and labour directly employed in the production of final goods, but also those employed indirectly in industries that produce intermediate inputs.

While the term "effective rate of MFP growth" was introduced by Hulten (1978), the distinction between the effective rate of MFP growth and standard MFP growth can be found in the Domar aggregation of industry MFP growth. Domar (1961) presented an aggregate MFP growth measure in the production of final demand products as the difference between output growth and the growth of total capital and labor inputs and showed that the contribution of an industry to aggregate MFP growth in the production of final demand products depends not only on its direct contribution to productivity gains in the production of final demand outputs, but also on an indirect contribution through productivity gains for intermediate inputs used by other industries.

The rest of this section begins with an example of a production process adapted from Domar (1961) to illustrate the difference between effective and standard MFP growth. It then presents the effective rate of MFP growth using the IO production framework, and shows that the effective MFP growth measure is more closely related to changes international competitiveness than the standard MFP growth measure.

2.1. *An Example*

This example is taken from Domar (1961). The objective is to measure multifactor productivity growth in the production of final demand product in an economy that consists of two industries. Industry one produces final goods Y_1 using capital K_1, labor L_1, and intermediate inputs M_2. Industry two produces intermediate inputs M_2 for industry one, using capital K_2 and labor L_2. The two industries have the following production function with constant returns to scale:

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

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

Standard MFP growth for the two industries, which 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, labor and intermediate inputs in the value of total gross output, averaged over two periods, and Δ denotes the difference between two periods.

Substituting (2) into (1) yields a production function for an integrated production process that relates total capital inputs and labor inputs to the production of final demand product. Taking the logarithm of the production function for the integrated production process and then taking the first difference with respect to time, we have 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 in the integrated sector for the production of final goods is the weighted sum of MFP growth in the two industries that comprise the integrated production sector, where the weights are the ratios of industry gross output to the value of output of final product.[5] This is the Domar aggregation.

The effective rate of MFP growth is the sum of productivity growth originating in the industry producing the final product (industry one) and productivity growth in the upstream industry producing intermediate input for the final product-producing sector (industry two). That is, the effective MFP growth considers the integrate production process for the production of final demand product and captures productivity gains in both upstream and final-product producing sector comprising the integrated production process. In contrast, the standard MFP growth as defined in equations (3) and (4) considers those two industries in isolation and measures productivity gains in those two industries separately.

[5]The weight for industry one is equal to one as calculated by the ratio of output value of industry one to output value of the final product. The weight for industry two is equal to γ_1 as calculated by the ratio of output value of industry two to output value of the final product.

2.2. *Effective Rate of Multifactor Productivity Growth*

In the section above, the effective rate of MFP productivity growth was presented in a simple case of an integrated production process where one industry specializes in the production of intermediate inputs and other industry use these intermediate inputs for the production of the final product. In general, industries often use parts of each other's outputs as intermediate inputs. For that complex case, Hulten (1978) showed that 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.

To simplify the calculation, Cas and Rymes (1991), Durand (1996), and Aulin-Ahmavaara (1999) assumed that the production function can be characterized by Leontief technologies (Leontief,1936, 1941). Using the input-output framework, they showed that the weights can be derived using the "Leontief inverse." The effective rate of MFP growth in those studies is estimated in a closed economy.

By contrast, in the present analysis, the measure is extended to an open economy to assess the effect of gains in the production of intermediate inputs in other countries on productivity growth and international competitiveness of domestic industries. To that end, single-country IO tables are extended to a multi-country setting.

A world input-output table is a combination of national input-output tables in which the use of products is broken down by their origin. For each country, flows of products for intermediate and final use are split into those produced domestically and those that are 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 used for production. The intermediates can be sourced from domestic industries or imported.

Table 1 presents the definitions of variables in the world input-output table and other related variables for presenting the effective MFP growth. The world input-output table can be presented in matrix form. It is assumed 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 (at home or abroad) or used as intermediate input in production (again, at home or abroad). 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. A global intermediate input coefficients matrix A of dimension (SNxSN) is further defined:[6]

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

TABLE 1

DE.NITIONS OF VARIABLES FOR ESTIMATING THE EFFECTIVE MFP GROWTH

Variables	Definitions
S	Number of sectors
N	Number of countries
F	Number of production factors
x	Column vector of gross output of dimension SN
A	Matrix of global intermediate input/outputcoefficients of dimension SN times SN
y	Column vector of global final demand of dimension SN
I	Identity matrix of SN times SN
c	Column vector of capital input per unit of gross output of dimension SN
v	Column vector of standard MFP growth for an industry based on gross output of dimension SN
e	Column vector of effective MFP growth for an industry of dimension SN

(6) $$A=\begin{bmatrix} A_{11} & A_{12}\dots & A_{1N} \\ A_{21} & A_{22}\dots & A_{2N} \\ \vdots & \vdots & \vdots \\ A_{N1} & A_{N2}\dots & A_{NN} \end{bmatrix}, \quad A_{ij}=\left\{a_{ij}(s,t)\right\}_{SxS}$$

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 domestic and foreign intermediate products.

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

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 in a compact form:

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

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

(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 required 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.

Standard and effective MFP growth

Standard MFP growth is defined for individual industries where output is gross output and inputs include capital, labor and intermediate inputs. It is estimated as the difference between output growth and the growth of combined capital, labor and intermediate inputs using the standard growth accounting framework.

Effective MFP growth is defined for the integrated sector for the production of final product. It can be calculated as the difference between the growth in the output of final product and the growth in the combined capital and labor inputs used directly and indirectly to produce the final product, where the weights are shares of direct and indirect capital and labor costs.

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

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

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 and costs of direct and indirect labor inputs and the costs of direct and indirect labor costs used for the production of a particular final product n.

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

$$e_n = i'\Delta\ln z_n - s'_{kn}\Delta\ln k_n - s'_{\ln}\Delta\ln l_n \tag{11}$$

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 labor cost shares in total costs.

Let v be the column vector of standard MFP growth based on gross output of dimension (SNx1), and e be the column vector of the 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.

It can be shown that the effective rate of MFP growth for the production of final product is equal to a weighted sum of standard MFP growth on gross output across all industries involved in the production of the final product where weights are equal to the value of production required for the production of one unit of final output (Cas and Rymes, 1991; Durand, 1996, and Aulin-Ahmavaara,1999):

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

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 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. Because the sum of value added in the total production is equal to the value of output of the final product (Timmer *et al*., 2012b), the sum of weights used for aggregation in equation (12) exceeds one. This is similar to Domar aggregation (Domar, 1961; Jorgenson *et al*., 2007).

While the effective MFP growth measure takes into account the amount of capital and labor inputs used in the foreign production of intermediate inputs, it is not a measure of MFP growth at the global level. Rather, it is a measure of MFP growth at the national level. But it captures the impact of productivity gains in foreign upstream industries that supply intermediate inputs. A measure of MFP growth for final product production at the global level entails estimating and then aggregating productivity growth across all industries and all countries involved in producing that final product.

The impact of productivity gains in domestic and foreign upstream industries

Equation (12) provides a decomposition of MFP growth in downstream production into those from upstream industries supplying intermediate inputs. The contribution of productivity gains in upstream industries to MFP growth in downstream production is measured by the MFP growth in the upstream industries times the value of production in the upstream industries required for the production of one unit of output.

The equation also provides a decomposition of the effective rate of MFP growth into a portion coming from domestic industries and a portion coming 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 a domestic industry.

MFP growth for the production of final demand product

The effective rate of MFP growth also provides an appropriate measure of MFP growth in the production of final demand products such as investment, consumption, and exports. It is equal to 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 the share of industry deliveries to the final demand in the value of the final demand. Or, it can be estimated as the weighted sum of effective MFP growth rates for the production of various investment products using the product mix of investment as weights (Durand, 1996).

A comparison of effective and standard MFP growth

The effective rate of MFP growth for the production of total final demand should be equal to standard MFP growth in the aggregate sector in a closed economy. To demonstrate this, 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:

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

where $\left(y/\sum_s y_s\right)$ 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), yields:

$$(14) \qquad EMFP = v'\left(x/\sum_s y_s\right).$$

In a closed economy, the value of final demand $\left(\sum_s y_s\right)$ 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. Because 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 effective MFP growth for the production of final demand is equal to standard aggregate MFP growth in a closed economy.[7]

However, the effective MFP growth will differ from the standard MFP growth in an open economy where industries purchase intermediate inputs from foreign industries. Effective MFP growth will surpass standard aggregate MFP growth if productivity growth is higher in the foreign production of intermediate inputs. On the other hand, effective MFP growth will be lower if productivity growth is lower in the foreign production of intermediate inputs.

2.3. *Multifactor Productivity Growth and Changes in International Competitiveness*

This section examines the relationship between MFP growth and changes in international competitiveness, which is restricted to the notion of the relative

[7]This discussion also shows that the effective MFP growth for the production of final demand products in a closed economy is equal to aggregate MFP growth calculated from the aggregation of industry MFP growth or so-called the bottom-up approach. For a discussion about the bottom-up approach as compared to the top-down approach for estimating aggregate MFP growth, see Jorgenson *et al*. (2007), Diewert (2012), Gu (2012), and Schreyer (2012).

output price or cost differentials between two countries (Jorgenson and Nishimizu, 1978; Durand and Giorno, 1987). The relative level of price competitiveness involves a comparison of the purchasing power parities of a product with the exchange rates. For example, the price competitiveness between Canada and the U.S. is the ratio of the number of U.S. dollars required in Canada to purchase the same amount of the product costing one U.S. dollar in the U.S. The price competitiveness of a domestic industry improves when the output price declines relative to that in other countries or the exchange rates depreciate against the other countries.

This paper argues that it is the effective MFP growth, not the standard MFP growth that is more likely to affect the evolution of the price competitiveness position of an industry. Hulten (1978) made a similar argument: it is the effective MFP growth that is more likely to affect the growth and evolution of an industry, not the standard MFP growth. While productivity gains at the final stage of production contribute to an improvement in competitiveness, productivity gains in upstream industries which include domestic services-producing industries and foreign intermediate input producing industries, are also important for improving effective MFP and price competitiveness.[8] The effective MFP growth captures both of those two effects.

As the effective MFP growth capture the productivity gains in upstream industries, it captures (or internalizes) in its measure the effect on output price resulting from productivity gains in their production of intermediate inputs. For that reason, the correlation between changes in output price and effective MFP growth will likely be stronger than that with standard MFP growth.

3. DATA

The analysis in this paper uses two databases: the World Input-Output Database (WIOD) (Timmer *et al.*, 2012b) and EU KLEMS database (O'Mahony and Timmer, 2009).

The world input-output tables cover 35 industries and six final demand categories in each of 40 countries for the 1995-to-2009 period. The WIOD is used to calculate the Leontief inverse matrix, as well as product expenditure shares, within each demand category (total final demand, consumption, investment and exports).

The EU KLEMS database provides data on economic growth and productivity for 25 of the 27 EU member states, as well as for Australia, Canada, Japan, and the U.S. It covers as many as 72 industries from 1970 to the present. As the data are available up to 2007 for most of the countries, the analysis for this paper covers the period 1995 to 2007.

The industrial classification in 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

[8]In addition to the effective MFP growth, the other determinant of the change in the price competitiveness is the difference in growth of the price of total capital and labor inputs used in the production. This in turn depends on relative capital intensity and relative capital/labor input prices in the integrated production sectors in two trading partners.

on the availability of productivity data in the EU KLEMS database, six country categories were defined: Canada, the U.S., Australia, Japan, the EU, and the rest of the world (ROW). The EU group includes only the 10 member countries for which productivity measures are available: Austria, Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, Spain, and the U.K. Because of the unavailability of data, productivity growth for the rest of the world is assumed to be zero. This assumption is not likely to affect the main results in the study, because 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 estimates of effective MFP growth in the production of final demand products for Canada, the U.S., Australia, Japan, and selected EU countries during the 1995-to-2000 and 2000-to-2007 periods. The 1990s were marked by strong growth in those countries. After 2000, economic growth declined in most of those developed countries with the bursting of dot-com bubbles and the recession of the early 2000s (Oliner *et al.*, 2007; van Ark, *et al.*, 2013).[9]

The extent to which production in the various countries/regions is globally integrated puts the estimates of effective MFP in context. The average share of intermediate inputs in gross output ranged from 45 percent to 52 percent across countries over the period 1995 to 2007. And, the imported share of total intermediate inputs also varied: 23 percent for Canada, 9 percent for the U.S., 12 percent for Australia, 7 percent for Japan, 10 percent for the EU countries and 13 percent for the rest of the world. Canada is highly integrated into upstream industries in the U.S., from which it imports an average of 14 percent of all its intermediate inputs (Gu and Yan, 2014).

The share of intermediate inputs imported from the rest of the world that includes China, India and other emerging economies is relatively small, though is increasing over time. For example, the EU countries purchased 8 percent of their intermediate inputs from the rest of the world for the period 1995 to 2007, while Canada, the U.S., Japan and Australia purchased about 5 percent of their intermediate inputs from the rest of the world.

4.1. *Standard Versus Effective Multifactor Productivity Growth for the Total Economy*

Standard and effective MFP growth estimates in the production of final demand products differ by country/region (Table 2). For Canada's total economy, effective MFP growth was lower than standard MFP growth during the 1995-to-2000 period, but higher after 2000. The lower effective MFP growth estimate before 2000 reflects the fact that Canadian industries source most imported intermediate inputs from the U.S., and productivity growth in the U.S. was lower than

[9]Rao *et al.* (2010) examined the factors behind the slower economic growth in Canada and the U.S. after 2000 with a focus on the role of investment in information and communication technologies.

TABLE 2

Average Annual Standard and Effective Multifactor Productivity (Mfp) Growth for Final Demand Products, By Country/Region, 1995 To 2000 And 2000 To 2007

	Standard MFP Growth	Effective MFP Growth
	Percent	
1995 to 2000		
Canada	0.94	0.86
U.S.	0.85	0.92
Australia	0.97	0.89
Japan	0.31	0.27
European Union	0.38	0.35
2000 to 2007		
Canada	−0.04	0.23
U.S.	0.45	0.37
Australia	−0.53	−0.2
Japan	1.34	1.18
European Union	0.35	0.26

Sources: Statistics Canada; authors' tabulation from world input-output tables and European Union-KLEMS (Capital, Labor, Energy, Materials and Services).

in Canada during that period.[10] The higher effective MFP growth estimate for Canada after 2000 reflects greater productivity growth for intermediate inputs in the U.S. in those years.

In the U.S., effective MFP growth exceeded standard MFP growth during the 1995-to-2000 period, because American industries purchase intermediate inputs from countries whose productivity growth for intermediate inputs tended to be high. After 2000, effective MFP growth was lower than standard MFP growth, because countries that supplied intermediate inputs had lower productivity growth at that time.

For the EU countries, the two measures were similar for the 1995-to-2000 period, but after 2000, effective MFP growth was lower than standard MFP growth.

The estimates of effective MFP growth presented here may be biased because it is assumed that no MFP growth occurred in countries not included in this analysis. If the share of intermediate inputs imported from those countries is small, this bias should be negligible, but if the share becomes large, the bias could be substantial.

To examine the size of the bias, effective MFP growth is re-estimated based on the assumption that MFP growth in the rest of world equaled that in American industries. Under this assumption, the estimate of effective MFP growth rose by about 0.1 percentage points, and exceeded standard MFP growth in all countries except Japan (Gu and Yan, 2014).

[10]The MFP growth rates from the EU KLEMS database may differ from those published by the national statistical agencies such as Statistics Canada and the U.S. Bureau of Labor Statistics. The difference is a result of difference in industry coverage, difference in assumptions made for estimating capital and labor inputs.

4.2. *Country Origins of Multifactor Productivity Growth in Total Economy*

To determine the extent to which nations have benefited from productivity growth abroad, effective MFP growth in the production of final products is decomposed into contributions of countries (Table 3). Domestic gains were the main driver of productivity growth, but differences across countries and time periods were sizeable. For example, between 1995 and 2000, 0.65 percentage points or three quarters of 0.86 percentage point annual growth in MFP in Canada was domestic, and about 0.19 percentage points came from productivity growth in the U.S.

Canada benefited more from productivity gains in the production of intermediate inputs in foreign countries than did the U.S., Australia, Japan or the EU countries. This was because Canada imported a larger share of intermediate inputs than did those countries, and productivity growth in the foreign supplier industries (notably, the U.S.) was higher than in Canada.

For the U.S., Australia, Japan and the EU countries, the contribution of productivity growth in the foreign production of intermediate inputs to MFP growth in the total economy is small. However, as will be shown below, the contribution of foreign productivity growth is significant in the production of manufacturing goods, investment and export goods in those countries despite their overall small contribution.

4.3. *Multifactor Productivity Growth by Final Demand Categories*

The rates of multifactor productivity growth for the production of investment and consumption products have implications for long term economic growth and business cycles. For example, Basu *et al*. (2013) found that in the U.S., productivity growth for investment products was negatively related to increases in hours, investment, consumption and output, whereas productivity growth for consumption products was positively related to increases in those variables. Therefore, it is important to have a correct measure of MFP growth for the production of those final demand products.

The effective MFP growth provides an appropriate framework for such measure. We have estimated effective MFP growth for the production of investment, consumption and export products in Table 3. MFP growth tended to be higher in the production of investment and export products than in the production of consumption products.[11] For instance, in the U.S., MFP growth in the production of investment, export and consumption products was 1.6 percent, 3.2 percent and 0.8 percent, respectively, in the pre-2000 period, and 0.04 percent, 2.1 percent and 0.4 percent after 2000. This can be attributed to relatively high productivity growth in industries that produce investment and export products (such as electrical and optical equipment, transport equipment), and slower growth in consumption-producing industries (such as real estate activities, public administration and health/social work).

The country origins of productivity gains differ across consumption, investment, and export products (Table 3). In general, productivity growth in foreign

[11]Basu *et al*. (2013) found similar results for the U.S.

TABLE 3

Country Origins of Effective Multifactor Productivity (Emfp) Growth, By Type of Product, 1995 To 2000 and 2000 To 2007

	1995 to 2000					2000 to 2007				
Type of product and country	Canada	U.S.	Australia	Japan	European Union	Canada	United States	Australia	Japan	European nion
EMFP growth in the production of Final demand product										
Canada	0.65	0.02	0.00	0.00	0.00	0.08	−0.01	0.00	0.00	0.00
U.S.	0.19	0.90	0.04	0.02	0.04	0.12	0.36	0.03	0.02	0.03
Australia	0.00	0.00	0.81	0.00	0.00	0.00	0.00	−0.26	−0.01	0.00
Japan	0.01	0.01	0.01	0.24	0.01	0.02	0.01	0.02	1.16	0.01
European Union	0.02	0.00	0.02	0.00	0.31	0.02	0.01	0.02	0.01	0.22
Total	0.86	0.92	0.89	0.27	0.35	0.23	0.37	−0.20	1.18	0.26
Consumption products										
Canada	0.39	0.01	0.00	0.00	0.00	0.09	−0.01	0.00	0.00	0.00
U.S.	0.12	0.73	0.04	0.01	0.03	0.09	0.43	0.03	0.01	0.03
Australia	0.00	0.00	0.84	0.00	0.00	0.00	0.00	−0.47	−0.01	0.00
Japan	0.01	0.01	0.01	0.10	0.01	0.01	0.01	0.01	1.09	0.01
European Union	0.01	0.00	0.02	0.00	0.33	0.01	0.01	0.01	0.00	0.19
Total	0.53	0.75	0.90	0.13	0.37	0.20	0.43	−0.41	1.09	0.22
Investment products										
Canada	1.47	0.03	0.00	0.00	0.00	0.05	0.00	−0.01	0.00	−0.01
U.S.	0.41	1.49	0.06	0.04	0.06	0.22	0.01	0.03	0.03	0.04
Australia	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.34	−0.01	0.00
Japan	0.03	0.02	0.02	0.57	0.01	0.04	0.02	0.02	1.38	0.02
European Union	0.03	0.01	0.03	0.01	0.19	0.03	0.01	0.02	0.01	0.32
Total	1.94	1.55	0.82	0.63	0.27	0.33	0.04	0.41	1.41	0.37
Export products										
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
European Union	0.02	0.01	0.02	0.01	0.64	0.03	0.02	0.02	0.01	0.72
Total	1.68	3.17	1.02	1.26	0.73	−0.16	2.09	−1.25	2.48	0.78

Sources: Statistics Canada; authors' tabulations from world input-output tables and European Union-KLEMS (Capital, Labor, Energy, Materials and Services).

TABLE 4

Country And Industry Origins Of Effective Multifactor Productivity Growth, 1995 To 2000

	Within Country		Outside Country		
	Within Industry	Outside Industry	Within Industry	Outside Industry	Total
	Percentage Points				
Canada					
Goods	1.23	0.19	0.33	0.07	1.82
Services	0.08	0.08	0.02	0.08	0.26
All	0.52	0.12	0.14	0.08	0.86
U.S.					
Goods	1.12	0.38	0.07	0.00	1.57
Services	0.55	0.11	0.00	0.02	0.68
All	0.71	0.19	0.02	0.01	0.92
Australia					
Goods	0.38	0.38	0.09	0.01	0.86
Services	0.82	0.02	0.01	0.05	0.90
All	0.66	0.15	0.04	0.04	0.89
Japan					
Goods	0.41	0.12	0.05	0.01	0.59
Services	0.03	0.04	0.00	0.01	0.08
All	0.18	0.07	0.02	0.01	0.27
European Union					
Goods	0.49	0.03	0.06	0.02	0.60
Services	0.10	0.07	0.00	0.02	0.20
All	0.25	0.05	0.03	0.02	0.35

Sources: Statistics Canada, authors' tabulations from world input-output tables and European Union-KLEMS (Capital, Labor, Energy, Materials and Services).

countries made a larger contribution to productivity growth in investment and export products than in consumption products. This was because industries producing investment and export products are more integrated with industries in foreign countries and tend to have higher productivity growth than do consumption-product industries. For example, during the 1995-to-2000 period, productivity growth in foreign industries contributed 0.14 percentage points to productivity growth for consumption products in Canada, but 0.47 and 0.37 percentage points to productivity growth for investment and export products.

4.4. *Offshoring and Multifactor Productivity Growth*

We have estimated the effective MFP growth for the production of final demand goods and services and examined the contribution of offshoring to MFP growth in their production (Tables 4 and 5). The effective MFP growth is found to be different in the production of goods and services. For the 1995-to-2000 period, due to large gains in the production of information and communication technologies, MFP growth in the production of goods was higher than in the production of services for all countries in the analysis except Australia. After 2000, in Canada and the U.S., productivity growth tended to be higher in the production of services, an outcome often attributed to the adoption of information and

TABLE 5
Country And Industry Origins of Effective Multifactor Productivity Growth, 2000 To 2007

	Within Country		Outside Country		
	Within Industry	Outside Industry	Within Industry	Outside Industry	Total
	Percentage Points				
Canada					
Goods	−0.22	0.15	0.22	0.05	0.21
Services	0.20	−0.03	0.02	0.06	0.25
All	0.04	0.04	0.10	0.06	0.23
U.S.					
Goods	0.10	0.22	0.02	0.01	0.35
Services	0.34	0.04	0.00	0.01	0.38
All	0.27	0.09	0.01	0.01	0.37
Australia					
Goods	0.03	−0.07	0.06	0.02	0.03
Services	−0.31	−0.06	0.01	0.04	−0.32
All	−0.20	−0.06	0.03	0.03	−0.20
Japan					
Goods	1.15	0.25	0.02	0.01	1.42
Services	0.94	0.10	0.00	0.00	1.04
All	1.01	0.15	0.01	0.00	1.18
European Union					
Goods	0.45	0.05	0.04	0.01	0.56
Services	0.01	0.05	0.01	0.02	0.08
All	0.17	0.05	0.02	0.02	0.26

Sources: Statistics Canada; authors' tabulations from world input-output tables and European Union-KLEMS (Capital, Labor, Energy, Materials and Services).

communication technologies in the service sector (Jorgenson *et al*., 2007; van Ark *et al*., 2008).

As a result of declining communications and trade costs, outsourcing and offshoring have increased in developed countries over the last 20 years.[12] Industries in developed countries purchase growing amounts of service and material intermediate inputs from other domestic industries (outsourcing) and from foreign countries (offshoring).

To examine the contribution of offshoring to productivity growth, the foreign and domestic components of aggregate productivity growth were decomposed into gains arising from intermediate service inputs and gains arising from goods intermediate inputs. The contributions to aggregate MFP growth were small, but the contributions of goods offshoring tended to be higher. For example, during the 1995-to-2000 period, services offshoring contributed 0.1 percentage points per year to MFP growth in Canada, while material offshoring (of purchase of goods as intermediate inputs from other countries) contributed 0.3 percentage points per year to MFP growth in goods production.

We have also estimated standard and effective MFP growth by industry for Canada, the U.S., and other countries covered in this paper (Gu and Yan, 2014).

[12]For evidence on offshoring for Canada, see Baldwin and Gu (2008) and Tang (2010)

A number of findings emerge from the analysis. First, the effective MFP growth tended to be higher than standard MFP growth at the industry level, as the effective MFP growth captures the impact of productivity gains in upstream industries. Second, offshoring and productivity gains in foreign countries made a larger contribution to effective MFP growth in manufacturing than non-manufacturing industries. This reflects the higher degree of integration of manufacturing industries in the world economy.

4.5. *Productivity Growth and International Competitiveness*

In this section, we examine the relationship between MFP growth and changes in output prices and international competitiveness. For that purpose, we estimate an equation that expresses annual 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 a function of effective productivity growth ($e_{i,t}$):

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

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

where α_t and β_t are period dummies.

The sample for the estimation consists of data on annual changes in output price and multifactor productivity for 31 industries over two sub-periods periods: 1995 to 2000 and 2000 to 2007. The equation is estimated separately for each country or region (Canada, the U.S., Australia, Japan, and the EU region).[13]

It is hypothesized that the coefficient β_1 on the effective MFP growth variable will be closer 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 in Table 6 show that, except for the EU countries, 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 the EU countries, the R-squared is similar for the two regressions. The greatest improvement in R-squared is 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 from the coefficient estimates on the MFP growth variables for Canada, the U.S. and Japan is consistent with the view that effective MFP growth is more closely related with changes in output price and international competitiveness. The correlation between effective MFP growth and change in output price is closer to minus one than is the correlation between standard MFP growth and change in output price. For example, the correlation of output price with effective

[13]For Canada, the data are available for all 31 industries, and there are 62 observations used for regression for Canada. For other countries and the EU region, the data are only available for 30 of the 31 industries and data on one of the 31 industries (private households with employed persons) are not available. There are 60 observations for those countries and the EU region.

TABLE 6

Explanation of Changes in Output Prices by Standard Versus Effective Productivity Growth Measures

	Canada	**U.S.**	**Australia**	**Japan**	**European Union**
Estimation of equation (16)					
Coefficient - alpha 1	−0.78 *	−1.20 *	−1.20 *	−1.25 *	−0.90 *
R-Square	0.17	0.66	0.31	0.43	0.26
t-Statistics	−3.49	−9.78	−3.67	−6.38	−4.11
Number of observations	62	60	60	60	60
Estimation of equation (17)					
Coefficient - beta 1	−0.95 *	−1.13 *	−1.24 *	−1.09 *	−0.75 *
R-Square	0.32	0.74	0.35	0.46	0.25
t-Statistics	−5.29	−12.08	−4.19	−6.77	−3.92
Number of observations	62	60	60	60	60

*P<0.05

Sources: World Input-Output Database and European Union—KLEMS (Capital, Labor, Energy, Materials and Services).

MFP growth is −0.95 across Canadian industries; the correlation with standard MFP growth is −0.78.

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

Overall, the empirical evidence provides some support for the view that the effective MFP growth is more closely associated with changes in output price and relative price competitiveness.

5. Conclusion

To capture the impact that productivity gains in upstream industries have on productivity growth and international competitiveness in downstream industries, this paper estimates the effective rate of MFP growth for Canada, the U.S., Australia, Japan, and selected EU countries. The effective rate of productivity growth accounts for productivity gains originating in upstream industries (both domestic and foreign) that supply intermediate material. By contrast, the standard estimate of MFP growth measures only productivity gains originating in the final production stage.

This analysis shows that MFP growth for small, open economies like Canada's, is partly attributable to gains in the production of intermediate inputs in foreign countries. Because Canada imported a larger share of intermediate inputs from foreign countries than did the other countries, and productivity growth in supplier industries (notably, in the U.S.) was higher, Canada benefited more from productivity gains in foreign countries than did the other countries in the analysis. Most of the foreign contribution to productivity growth is from imports of material inputs (material offshoring) rather than services (services offshoring). This reflects a higher share of material inputs in total intermediate imports, and relatively high productivity growth in the production of material inputs.

For other countries such as the U.S., Japan and the EU countries, the contribution of productivity growth in intermediate inputs production to MFP growth in the total economy is small. However, as a result of more extensive integration in the production of manufacturing goods, and the investment and export products in the global economy, productivity gains in foreign countries made a significant contribution to effective MFP growth in their production in those countries.

This analysis in this paper is based on the EU KLEMS database and World IO tables. The measure of effective MFP growth in this paper depends on the quality of underlying industry level data in those sources. Improvement of the KLEMS database and input/output tables by national statistical agencies, international statistical agencies and international research initiatives 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.

This paper has focused on changes in effective MFP growth and its relationship with changes in relative price competitiveness. The paper argues that it is the effective MFP growth, not the standard MFP growth that is more closely associated with changes in output price and international competitiveness. The effective MFP growth and the framework developed in this paper provide a decomposition of changes in effective MFP and price competitiveness. The changes in the effective MFP can be decomposed into productivity gains in the final stage of production and productivity gains in foreign and domestic upstream industries. This paper shows that offshoring contributes to improvements in international competitiveness through its positive effect on effective MFP growth in domestic production.

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