

Catalogue no. 15-206-X  
ISSN 1710-5269  
ISBN 978-1-100-24789-2

## The Canadian Productivity Review

# Productivity Growth and International Competitiveness

by Wulong Gu and Beiling Yan

Release date: September 9, 2014



 Statistics Canada Statistique Canada

Canada 

## How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, [www.statcan.gc.ca](http://www.statcan.gc.ca).

You can also contact us by

email at [infostats@statcan.gc.ca](mailto:infostats@statcan.gc.ca),

telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following toll-free numbers:

- |   |                |
|---|----------------|
| • Statistical Information Service                             | 1-800-263-1136 |
| • National telecommunications device for the hearing impaired | 1-800-363-7629 |
| • Fax line  | 1-877-287-4369 |

## Depository Services Program

- |                  |                |
|------------------|----------------|
| • Inquiries line | 1-800-635-7943 |
| • Fax line       | 1-800-565-7757 |

## To access this product

This product, Catalogue no. 15-206-X, is available free in electronic format. To obtain a single issue, visit our website, [www.statcan.gc.ca](http://www.statcan.gc.ca), and browse by “Key resource” > “Publications.”

## Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, Statistics Canada has developed standards of service that its employees observe. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on [www.statcan.gc.ca](http://www.statcan.gc.ca) under “About us” > “The agency” > “Providing services to Canadians.”

Published by authority of the Minister responsible for  
Statistics Canada

© Minister of Industry, 2014

All rights reserved. Use of this publication is governed by the  
Statistics Canada Open Licence Agreement ([www.statcan.gc.ca/reference/licence-eng.htm](http://www.statcan.gc.ca/reference/licence-eng.htm)).

Cette publication est aussi disponible en français.

## Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

## Standard symbols

The following symbols are used in Statistics Canada publications:

- |                |  |
|----------------|--|
| .              | not available for any reference period   |
| ..             | not available for a specific reference period  |
| ...            | not applicable   |
| 0              | true zero or a value rounded to zero   |
| 0 <sup>s</sup> | value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded |
| P              | preliminary  |
| r              | revised  |
| X              | suppressed to meet the confidentiality requirements of the <i>Statistics Act</i>                                   |
| E              | use with caution   |
| F              | too unreliable to be published   |
| *              | significantly different from reference category ( $p < 0.05$ )   |

# Productivity Growth and International Competitiveness

by

Wulong Gu and Beiling Yan  
Economic Analysis Division, Statistics Canada

15-206-X No. 037

ISSN 1710-5269

ISBN 978-1-100-24789-2

September 2014

## The Canadian Productivity Review

*The Canadian Productivity Review* is a series of applied studies that address issues involving the measurement, explanation, and improvement of productivity. Themes covered in the review include, but are not limited to, economic performance, capital formation, labour, prices, environment, trade, and efficiency at both national and provincial levels. *The Canadian Productivity Review* publishes empirical research, at different levels of aggregation, based on growth accounting, econometrics, index numbers, and mathematical programming. The empirical research illustrates the application of theory and techniques to relevant public policy issues.

All papers in *The Canadian Productivity Review* series go through institutional and peer review to ensure that they conform to Statistics Canada's mandate as a government statistical agency and adhere to generally accepted standards of good professional practice.

The papers in the series often include results derived from multivariate analysis or other statistical techniques. It should be recognized that the results of these analyses are subject to uncertainty in the reported estimates.

The level of uncertainty will depend on several factors: the nature of the functional form used in the multivariate analysis; the type of econometric technique employed; the appropriateness of the statistical assumptions embedded in the model or technique; the comprehensiveness of the variables included in the analysis; and the accuracy of the data utilized. The peer group review process is meant to ensure that the papers in the series have followed accepted standards, in order to minimize problems in each of these areas.

Publications Review Committee  
Analytical Studies Branch, Statistics Canada  
18th Floor, R.H. Coats Building  
Ottawa, Ontario K1A 0T6

## Acknowledgements

We would like to thank John Baldwin, Andrew Sharpe, Larry Shute, Aaron Sydor, Jianmin Tang, Hui Wei, and participants at the IARIW-UNSW Special Conference on "Productivity Measurement, Drivers and Trend" in Sydney, Australia, for helpful discussions and detailed comments.

# Table of contents

<b>Abstract</b> .....	<b>5</b>
<b>Executive summary</b> .....	<b>6</b>
<b>1 Introduction</b> .....	<b>7</b>
<b>2 Methodology</b> .....	<b>9</b>
2.1 An example .....	10
2.2 Effective rate of multifactor productivity growth .....	11
2.3 Multifactor productivity growth and international competitiveness.....	16
<b>3 Data</b> .....	<b>17</b>
<b>4 Empirical evidence</b> .....	<b>18</b>
4.1 Country origins of intermediate inputs .....	18
4.2 Standard versus effective multifactor productivity growth for the total economy .....	19
4.3 Country origins of multifactor productivity growth in the total economy .....	21
4.4 Multifactor productivity growth by final demand categories.....	23
4.5 Offshoring and multifactor productivity growth.....	23
4.6 Multifactor productivity growth by industry in Canada and the United States.....	26
4.7 Productivity growth and international competitiveness .....	31
<b>5 Conclusion</b> .....	<b>33</b>
<b>6 Appendix</b> .....	<b>34</b>
<b>References</b> .....	<b>39</b>

## Abstract

This paper presents estimates of effective multifactor productivity (MFP) growth for Canada, the United States, Australia, Japan and selected European Union (EU) countries, based on the EU KLEMS productivity database and the World Input-Output Tables. Effective MFP growth captures the impact of the productivity gains in upstream industries on the productivity growth and international competitiveness of domestic industries, thereby providing an appropriate measure of productivity growth and international competitiveness in the production of final demand products such as consumption, investment and export products. A substantial portion of MFP growth, especially for small, open economies such as Canada's, is attributable to gains in the production of intermediate inputs in foreign countries. Productivity growth tends to be higher in investment and export products than for the production of consumption products. Technical progress and productivity growth in foreign countries have made a larger contribution to production growth in investment and export products than in consumption products. The analysis provides empirical evidence consistent with the hypothesis that effective MFP growth is a more informative relevant indicator of international competitiveness than is standard MFP growth.

## Executive summary

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 productivity and competitiveness.

This paper examines the impact that productivity gains in upstream industries supplying intermediate inputs have on productivity growth and international competitiveness in domestic industries. It proposes and estimates the effective rate of multifactor productivity (MFP) growth for Canada, the United States, Australia, Japan, and selected European Union (EU) countries, using data from the EU KLEMS productivity database and the World Input-Output Tables. The effective rate of MFP growth accounts for the effect of productivity gains originating in upstream industries (both domestic and foreign) that supply intermediate inputs. By contrast, the standard measure of MFP growth captures only the productivity gains originating in the final production stage. The paper finds:

- A substantial portion of MFP growth, especially for small, open economies like Canada's, originates from productivity gains in the production of intermediate inputs in foreign countries. Because Canada imported a larger share of intermediate inputs from foreign countries than did other countries included in the study and productivity growth in its supplier industries found elsewhere (notably, in the United States) was higher, Canada benefits more from productivity gains in foreign countries than did other countries.
- Most of the foreign contribution to productivity growth is from imports of material inputs (material offshoring) rather than services inputs (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.
- Technical progress and productivity growth in foreign countries made a larger contribution to MFP growth in the production of investment and export products, compared with the production of consumption products. This is because domestic industries producing investment and exports are more integrated with industries in foreign countries and those industries tend to have higher productivity growth than do consumption-product producing industries.
- As a result of more extensive integration of manufacturing industries into the world economy via cross-border trade, productivity gains in foreign countries made a larger contribution to the MFP growth in manufacturing industries than in non-manufacturing industries.

This paper provides empirical evidence that is consistent with the hypothesis that effective MFP growth is a more appropriate indicator of international competitiveness than are standard measures of MFP growth, because the former is more closely related to the decline in output price and improvement in international competitiveness across industries.

# 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 productivity and competitiveness (OECD 2012).<sup>1</sup> Altomonte and Ottaviano (2011), for instance, find that the competitiveness of firms and industries is positively associated with international production-sharing and purchases of imported intermediate inputs. In addition, the literature on international research and development (R&D) and technology spillovers since Coe and Helpman (1995) has found that through the import of intermediate inputs, foreign technical progress contributes to the productivity growth and international competitiveness of domestic industries.

However, the rise of global production poses challenges to analyses of countries' competitiveness. Measures such as gross exports are based on the assumption that all production activities take place in individual economies, and are, therefore, less informative for the policy debate. Consequently, new measures are being developed. For example, Johnson and Noguera (2011) and Koopman et al. (2012) propose a measure of domestic value-added content of exports. Timmer et al. (2012) and van Ark et al. (2013) propose a measure of "global value chain income" that is based on the value-added by countries along the international production chain.

Similarly, the current measure of multifactor productivity (MFP) growth fails to capture the impact that productivity gains in the production of intermediate inputs have on the productivity gains of domestic industries.<sup>2</sup> This is because it measures only gains originating in a particular industry. On the other hand, an alternate measure—the effective rate of MFP growth—captures the impact of productivity gains in upstream industries (at home and abroad) supplying intermediate inputs on the growth and international competitiveness of a domestic industry. This paper argues that the latter is a more appropriate measure of international competitiveness.

The effective rate of MFP growth was proposed by Domar (1961), Rymes (1971), Hulten (1978), Cas and Rymes (1991), and has been used in a number of studies (Durand 1996; Aulin-Ahmavaara 1999). 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 reflected in 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, which are captured by the standard industry MFP measures that are currently produced.

The two measures serve different purposes. If the focus of analysis is the efficiency with which domestic industries use inputs in production, standard MFP growth, which considers industries in isolation, is the proper measure. However, to assess the competitiveness and growth of industries, the appropriate measure is the effective rate of MFP growth, which assesses the gains along the entire chain involved in producing goods and services for final use. The effective rate of MFP growth is also useful for understanding international competitiveness, because, as will be shown, it is more closely related to export growth and product prices.

---

1. Yakabuski (2013) contends 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 their economies makes all three NAFTA countries richer, more competitive and better-positioned to conquer global markets.

2. The standard measure of industry MFP 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 1976).

This paper has a number of objectives.

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

Second, the effective rates of MFP growth are decomposed into the contributions of individual countries and industries to determine the origins of the gains and to examine the contribution of trends toward sourcing intermediate inputs abroad or offshoring to productivity growth.<sup>3</sup>

Third, the correlation between the effective rate of MFP growth and the price of output across industries is estimated and compared with the correlation between standard MFP growth and product prices across industries. This demonstrates that the effective rate of MFP growth is a more informative measure of competitiveness, compared with standard MFP growth.

This paper is related to previous studies of differences in MFP growth in the production of investment and consumption goods and their implications for economic growth. 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 information and communications technologies (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 labour inputs used directly and indirectly in their production.

The present study is also related to a paper by Basu and Fernald (2010) that estimated MFP growth in the production of investment and consumption goods for the United States. Similarly to this paper, Basu and Fernald (2010) estimated 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. 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 traditional growth accounting framework as developed (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 productivity growth using a measure called the inter-industry productivity growth estimate (Statistics Canada 1994; Durand 1996). Based on that measure, Gu and Whewell (2005) showed that after implementation of the Canada–United States Free Trade Agreement (FTA) in 1989, effective MFP growth accelerated in the production of export goods, compared with other goods and services, and thus, inferred that the FTA raised the productivity of Canadian industries exposed to international trade.

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 Tables (WIOT) and the EU KLEMS productivity database, which became available as a result of two

---

3. This paper considers only the impact of productivity gains in foreign intermediate inputs on productivity growth in the domestic production of final demand products. It does not consider the effect of gains in the production of imported capital on domestic production. Such analysis requires a departure from the 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.



major international initiatives: the WIOT and EU KLEMS. Section 3 describes the data used for empirical analysis. Section 4 focuses on the decomposition results and presents empirical evidence that the effective rate of MFP growth is more appropriate as a measure of industry competitiveness for Canada. 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 technical change originating in a particular sector, but also on technical progress in the production of intermediate inputs to the sector (such as steel, rubber and plastics).

The effective rate of productivity growth measures technical progress in an integrated production sector. The concept of an integrated production sector for estimating effective MFP growth was introduced by Domar (1961). The integrated production sector 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. Input for the integrated production sector includes not only capital and labour directly employed in the production of final goods, but also those employed indirectly in industries that produce intermediate inputs.

Hulten (1978) 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.<sup>4</sup> 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. By contrast, in the Domar aggregation of standard MFP growth across industries, weights are estimated as the ratio of industry gross output in total value of final demand, and sum to more than one, because part of industry gross output is used as intermediate inputs (Domar 1961).

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 is also apparent in the Domar aggregation of industry MFP growth. Domar (1961) showed that the contribution of an industry to aggregate MFP growth in the production of final demand outputs depends not only on its direct contribution to 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 presents an example of a production process adapted from Domar to illustrate the difference between effective and standard MFP growth. The effective rate of MFP growth is then presented using the input-output production framework, and is shown to be more closely related to the competitiveness of industries.

---

4. This is true only in a closed economy, where the industries purchase intermediate inputs only from other domestic industries, as shown in Section 2.

## 2.1 An example

This example is taken from Domar (1961). Let an economy consist 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:

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

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

Standard MFP growth for the two industries, which measures shifts in the production function, can be estimated as:

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

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

$\alpha_1$ ,  $\beta_1$ ,  $\gamma_1$ ,  $\alpha_2$  and  $\beta_2$  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 the production of final goods. Taking logarithms of the resulting production function for the integrated production process and differentiating with respect to time, the effective rate of MFP growth for the production of final goods is obtained:

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

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 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. Effective MFP growth captures productivity gains in both industries in the production of the final product. By contrast, standard MFP growth shown in Equations (3) and (4) measures productivity gains that originate in those two industries.

This example pertains to a closed economy, but can be extended to an open economy. Suppose that intermediate inputs are produced abroad and that the domestic economy consists of one industry that purchases the intermediate inputs from the foreign country. The standard estimate of MFP growth is measured using Equation (3); the effective rate of MFP growth, given in Equation (5), is the weighted sum of MFP growth in the domestic production industry and 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

In Subsection 2.1, the effective rate of MFP growth was presented in a simple case of integration. For a complex case, 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 functions of various substitution elasticities and commodity shares (Hulten 1978). 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). 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 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 the international competitiveness of domestic industries. To that end, single-country input-output tables are extended to a multi-country setting (Timmer 2012).

Table 1 presents a schematic outline of a 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 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.

**Table 1**  
**Schematic outline of a world input-output table, three regions**

	Country A intermediate industry	Country B intermediate industry	ROW C intermediate industry	Country A final demand	Country B final demand	ROW C final demand	Total
Country A industry	Intermediate use by country A of domestic output	Intermediate use by country B of exports from country A	Intermediate use by ROW C of exports from country A	Final use by country A of domestic output	Final use by country B of exports from country A	Final use by ROW C of exports from country A	Total output in country A
Country B industry	Intermediate use by country A of exports from country B	Intermediate use by country B of domestic output	Intermediate use by ROW C of exports from country B	Final use by country A of exports from country B	Final use by country B of domestic output	Final use by ROW C of exports from country B	Total output in country B
ROW C industry	Intermediate use by country A of exports from ROW C	Intermediate use by country B of exports from ROW C	Intermediate use by ROW C of domestic output	Final use by country A of exports from ROW C	Final use by country B of exports from ROW C	Final use by ROW C of domestic output	Total output in ROW C
Value added	Value added in country A	Value added in country B	Value added in ROW C	...	...	...	...
Total output	Total output in country A	Total output in country B	Total output in ROW C	...	...	...	...

... not applicable

**Note:** Adapted by authors from the source below.

**Source:** M.P. Timmer. 2012. *The World Input-Output Database (WIOD): Contents, Sources and Methods*. WIOD Working Paper Series Number 10.

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 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  $(SN \times 1)$ , which is obtained by stacking output levels in each country-sector. Define  $y$  as the vector of dimension  $(SN \times 1)$  that is constructed by stacking world final demand for output from each country-sector. A global intermediate input coefficients matrix  $A$  of dimension  $(SN \times SN)$  is further defined:<sup>5</sup>

$$A = \begin{bmatrix} A_{11} & A_{12} \dots & A_{1N} \\ A_{21} & A_{22} \dots & A_{2N} \\ \vdots & \vdots & \vdots \\ A_{N1} & A_{N2} \dots & A_{NN} \end{bmatrix}. \quad (6)$$

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:

$$\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \dots & A_{1N} \\ A_{21} & A_{22} \dots & A_{2N} \\ \vdots & \vdots & \vdots \\ A_{N1} & A_{N2} \dots & A_{NN} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix} + \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix}, \quad (7)$$

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:

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

---

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 identity:

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

where  $I$  is an  $(SN \times SN)$  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  $(SN \times 1)$ , and  $e$  be the column vector of effective rate of MFP growth of dimension  $(SN \times 1)$  for the production of final product, which are both obtained by stacking MFP growth in each country-sector.

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

Effective MFP growth in producing final product  $n$  can be calculated as the difference between the difference in the growth in the output of the final product and the growth in the combined capital and labour inputs used directly and indirectly to produce 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. 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 needed for production of this final product by the capital input coefficients vector  $c$ :

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

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 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:

$$e_n = d \ln z_n - s'_{kn} d \ln k_n - s'_{ln} d \ln l_n \quad (11)$$

where the prime (') 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.

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):

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

As discussed above, 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 are 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 2012), the sum of weights used for aggregation in Equation (13) exceeds one. This is similar to the Domar aggregation (Domar 1961; Jorgenson et al. 2007).

Equation (12) also decomposes 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 the production of final product  $n$ .

The effective rate of MFP growth for the production of a category 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 shares of industry deliveries to the final demand in the value of the final demand (Durand 1996).

The effective rate of MFP growth for the production of total final demand is 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:

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

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:

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

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. 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.<sup>6</sup>

If industries source intermediate inputs from domestic industries, effective MFP growth for the production of final demands will generally be equal to standard MFP growth in the total economy. The two will diverge if domestic industries purchase intermediate inputs from foreign countries, and if productivity growth differs for domestic and foreign production of intermediate inputs. Effective MFP growth will surpass standard aggregate MFP growth if productivity growth is higher for the foreign 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 international competitiveness

International competitiveness can be defined as the relative output price between two countries (Jorgenson and Nishimizu 1978; Ball et al. 2010; Lee and Tang 2000). The international competitiveness of a domestic industry improves when the output price declines relative to that in other countries. To be a good indicator of international competitiveness, MFP growth should be significantly and negatively correlated with the change in output price and the correlation coefficient between MFP growth and changes in output price is close to minus one.

In previous empirical studies, the standard estimate of MFP growth has been found to be negatively related to the change in output price across industries. 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, empirical evidence is presented that the correlation of output price changes with effective MFP growth tends to be stronger than its correlation with standard MFP growth and the correlation coefficient between effective MFP growth and changes in output price is found to be closer to the value of minus one across products. This is interpreted as evidence that effective MFP growth is a more informative measure of international competitiveness.

To see why this is the case, the dual approach for measuring productivity growth is used (Jorgenson and Griliches 1967; and for a survey, see Diewert 2008). According to the dual approach, MFP growth is the difference between changes in input prices and changes in output prices. Alternatively, changes in output prices can be written as the difference between changes in input prices and changes in MFP from the dual approach:

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

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  $\varepsilon_n$  is error term.

MFP in Equation (15) can be either standard MFP or effective MFP. For standard MFP, the equation expresses the changes in gross output price as the difference in the changes in the weighted sum of prices of capital, labour and intermediate inputs and changes in MFP. For effective MFP, the equation expresses the change in the price of a final product as the difference in the weighted sum of prices of capital and labour inputs used both directly and indirectly in the production of the final product and changes in effective MFP.

---

6. The 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 the bottom-up approach. For a discussion about the bottom-up approach as compared to the top-down approach, see Jorgenson et al. (2007), Diewert and Yu (2012), Gu (2012), and Schreyer (2012).



In general, the correlation between MFP growth and changes in output price is minus one ( $-1$ ) if changes in input prices are not correlated 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 is positive or negative.<sup>7</sup>

Standard MFP growth is equal to the difference in changes in the prices of capital, labour and intermediate inputs and changes in output prices. The correlation between standard MFP growth and output price changes will be equal to minus one if all input prices, including those of capital, labour and intermediate inputs, are assumed to be invariant to or uncorrelated with MFP growth. This is highly implausible, because the price of intermediate inputs is likely to be negatively correlated with standard MFP growth across industries and over time. This is true since a share of intermediate inputs used in the industries, especially in the more aggregated industries, is produced within the same industries. MFP growth and technical progress in the industries will lead to the decline in the price of the intermediate inputs used in the same industries. For example, the price of semiconductors fell dramatically because of rapid technical progress in their manufacture.

Effective MFP growth in producing a product is equal to the difference in changes in the prices of capital and labour inputs used directly and indirectly in production and changes in the output price. The correlation between effective MFP growth and output price changes is equal to minus one if the prices of capital and labour inputs are assumed to be invariant to or uncorrelated with MFP growth in the production of the final product; it does not require the assumption that the price of intermediate inputs is invariant to MFP growth. Essentially, effective MFP growth already captures the effect of technical change in the production of intermediate inputs on the price of final product.

The strong correlation (equal to minus one) between changes in effective MFP and changes in final product prices does require the assumption that the prices of capital and labour inputs are invariant to the MFP growth in the production of final products. That is more plausible if the prices of labour and capital services tend to be equalized across industries as a result of factor mobility across industries and are therefore not correlated with changes in MFP.<sup>8</sup>

### 3 Data

This analysis uses two databases: the World Input-Output Database (WIOD) (Timmer 2012) and the EU KLEMS productivity database (O'Mahony and Timmer 2009).

The WIOT are an extension of the national input-output tables, which show the use of products for intermediate or final use. The difference from the national tables is that the use of products is broken down by country of origin. For a country, flows of products for both intermediate and final use are split into those that are domestically produced or those that are imported. In addition, the WIOT show in which foreign industry the product is produced. Because information on the division 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 to three separate use categories (intermediate, investment and consumption)—is used to estimate the division for the WIOT.<sup>9</sup>

---

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

8. This is true in most of the countries examined in the paper.

9. The import proportionality assumption used in the construction of the WIOT improves upon the more restrictive proportionality assumption employed in previous studies. Those studies apply a product’s economy-wide import share for all use categories, which, as shown in Feenstra and Jensen (2012) and Baldwin et al. (2013), can generate biased estimates.

The WIOT cover 35 industries and 6 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 export).

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

The industrial classification in the WIOD and the EU KLEMS database are consistent with the European NACE 2 statistical classification of economic activities. 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, six country categories were defined: Canada, the United States, Australia, Japan, the European Union, 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 United Kingdom. Because of the unavailability of data, productivity growth for the rest of the world is assumed to be zero. This assumption does not 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 United States, Australia, Japan, and the European Union.

## **4 Empirical evidence**

This section presents estimates of effective MFP growth in the production of final demand products for Canada, the United States, Australia, Japan, and selected EU countries during the 1995-to-2000 and 2000-to-2007 periods. These periods were chosen because pre- and post-2000 economic conditions varied sharply: the 1990s were marked by strong growth, but after 2000, most of these countries experienced deep recessions.

### **4.1 Country origins of intermediate inputs**

The extent to which production in the various countries or regions is globally integrated puts the estimates of effective MFP in context. Averaged over the years 1995, 2000 and 2007, the share of intermediate inputs in gross output ranged from 45% to 52% across countries. However, the imported share of total intermediate inputs varied: 23% for Canada, 9% for the United States, 12% for Australia, 7% for Japan, 10% for the EU countries and 13% for the rest of the world (Table 2). Canada is highly integrated into upstream industries in the United States, from which it imports an average of 14% of all its intermediate inputs.

**Table 2**  
**Country origins of intermediate inputs, selected countries, averaged over 1995, 2000 and 2007**

	Canada	United States	Australia	Japan	European Union	Rest of the world
	percent					
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, 2000 and 2007	23	9	12	7	10	13
<b>Country origins of intermediate inputs – average country share of total intermediate inputs, 1995, 2000, 2007</b>						
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
European Union	3	2	3	1	90	6
Rest of the world	5	5	6	5	8	87
Total	100	100	100	100	100	100
	percentage points					
<b>Changes in the country share of intermediate inputs between 1995 and 2007</b>						
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
European Union	-1	0	-1	0	-4	0
Rest of the world	3	3	3	5	4	2

**Notes:** Authors' tabulation based on data from the source below. Percentages may not add up to 100 because of rounding.

**Source:** World Input-Output Database.

## 4.2 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 or region (Table 3). 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 United States, and productivity growth in the United States was lower than in Canada during that period. The higher effective MFP growth estimate for Canada after 2000 reflects greater productivity growth for intermediate inputs in the United States in those years.

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

	Standard MFP growth	Effective MFP growth
	percent	percent
<b>1995 to 2000</b>		
Canada	0.94	0.86
United States	0.85	0.92
Australia	0.97	0.89
Japan	0.31	0.27
European Union	0.38	0.35
<b>2000 to 2007</b>		
Canada	-0.04	0.23
United States	0.45	0.37
Australia	-0.53	-0.20
Japan	1.34	1.18
European Union	0.35	0.26

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

In the United States, 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 (Appendix Table 12). Under this assumption, the estimate of effective MFP growth rose by about 0.1 percentage point, and exceeded standard MFP growth in all countries except Japan.

### **4.3 Country origins of multifactor productivity growth in the 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 4). 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 the 0.86-percentage-point annual growth in MFP in Canada was domestic, and about 0.19 percentage points came from productivity growth in the United States. By comparison, almost all productivity growth in the United States came from the within-country component.

**Table 4**  
**Country origins of effective multifactor productivity growth**

Effective MFP growth in the production of:	1995 to 2000					2000 to 2007				
	Canada	United States	Australia	Japan	European Union	Canada	United States	Australia	Japan	European Union
	percentage points									
<b>Final demand product</b>										
Canada	0.65	0.02	0.00	0.00	0.00	0.08	-0.01	0.00	0.00	0.00
United States	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
<b>Consumption products</b>										
Canada	0.39	0.01	0.00	0.00	0.00	0.09	-0.01	0.00	0.00	0.00
United States	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
<b>Investment products</b>										
Canada	1.47	0.03	0.00	0.00	0.00	0.05	0.00	-0.01	0.00	-0.01
United States	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
<b>Export products</b>										
Canada	1.31	0.03	0.00	0.00	0.00	-0.42	-0.01	-0.01	0.00	0.00
United States	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

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity. Figures may not add up to totals because of rounding.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

For some nations, the country origins of MFP growth changed over time. Canada's within-country contribution declined from three-quarters in the pre-2000 period to around one-third after 2000, as the contribution from the United States rose from about one-fifth to just over half. By contrast, for the United States, the within-country contribution accounted for almost all productivity growth in both periods.

Canada benefited more from productivity gains in the production of intermediate inputs in foreign countries than did the United States, 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 United States) was higher.

#### **4.4 Multifactor productivity growth by final demand categories**

Productivity growth and technical progress for the production of investment and consumption products have had different economic trajectories over time. For example, Basu and Fernald (2010) found that in the United States, 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.

Productivity growth tended to be higher in the production of investment and export products than in the production of consumption products (Table 4).<sup>10,11</sup> For instance, in the United States, MFP growth in the production of investment, export and consumption products was 1.6%, 3.2% and 0.8%, respectively, in the pre-2000 period, and 0.04%, 2.1% and 0.4% 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) (Appendix Tables 13, 14, 15, and 16).

The country origins of productivity gains differ across consumption, investment, and export products (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 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, technical progress 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.

#### **4.5 Offshoring and multifactor productivity growth**

Effective MFP growth differs in the production of goods and services (Table 5 and Table 6). For the 1995-to-2000 period, due to large gains in the production of ICT, 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 United States, productivity growth tended to be higher in the production of services, an outcome often attributed to the adoption of ICT (Jorgenson et al. 2007; van Ark et al. 2008).

---

10. Basu and Fernald (2010) found similar results for the United States.

11. 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 Appendix Tables 13, 14, 15, and 16.

**Table 5**  
**Country and industry origins of multifactor productivity growth, 1995 to 2000**

	Within the country		Outside the country		Total
	Within industry	Outside industry	Within industry	Outside industry	
percentage points					
<b>Canada</b>					
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
<b>United States</b>					
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
<b>Australia</b>					
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
<b>Japan</b>					
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
<b>European Union</b>					
Goods	0.49	0.03	0.06	0.01	0.60
Services	0.10	0.07	0.00	0.02	0.20
All	0.25	0.05	0.03	0.02	0.35

**Note:** Authors' tabulation based on data from the sources below.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.



**Table 6**  
**Country and industry origins of multifactor productivity growth, 2000 to 2007**

	Within the country		Outside the country		Total
	Within industry	Outside industry	Within industry	Outside industry	
percentage points					
<b>Canada</b>					
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
<b>United States</b>					
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
<b>Australia</b>					
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
<b>Japan</b>					
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
<b>European Union</b>					
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

**Note:** Authors' tabulation based on data from the sources below.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

As a result of declining communications cost and trade costs, outsourcing and offshoring have increased in developed countries over the last 20 years (Baldwin and Gu 2008). 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 intermediate goods inputs. The contributions of services offshoring 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 0.08 percentage points per year to MFP growth in goods production in Canada, while material offshoring (or purchase of goods as intermediate inputs from other countries) contributed 0.33 percentage points per year to MFP growth in goods production.

## **4.6 Multifactor productivity growth by industry in Canada and the United States**

This section presents estimates of standard and effective MFP growth by industry for Canada (Table 7 and Table 8) and the United States (Table 9 and Table 10). At the industry level, effective MFP growth tended to be higher than standard MFP growth.

Tables 7, 8, 9, and 10 also show effective MFP growth for Canadian and American industries by the domestic and foreign contribution. 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 into the world economy.

**Table 7****Country origin of multifactor productivity growth by industry, Canada, 1995 to 2000**

World Input-Output Database industry name (code)	Country contribution to effective MFP						
	Standard MFP	Effective MFP	Canada	United States	Australia	Japan	European Union
				percent			
Agriculture, hunting, forestry and fishing (AtB)	1.5	2.3	2.2	0.1	0.0	0.0	0.0
Mining and quarrying (C)	-1.6	-1.4	-1.5	0.1	0.0	0.0	0.0
Food products, beverages and tobacco (15t16)	0.2	1.2	1.0	0.1	0.0	0.0	0.0
Textiles, textile products, leather and footwear (17t19)	1.1	1.8	1.6	0.2	0.0	0.0	0.0
Wood and products of wood and cork (20)	1.5	2.8	2.6	0.1	0.0	0.0	0.0
Pulp, paper, paper products, printing and publishing (21t22)	1.2	1.9	1.8	0.1	0.0	0.0	0.0
Coke, refined petroleum products and nuclear fuel (23)	0.1	-0.2	-0.2	0.0	0.0	0.0	0.0
Chemical and chemical products (24)	1.4	1.8	1.8	0.0	0.0	0.0	0.0
Rubber and plastic products (25)	1.3	1.9	1.8	0.1	0.0	0.0	0.0
Other non-metallic mineral products (26)	1.8	2.3	2.2	0.1	0.0	0.0	0.0
Basic metals and fabricated metal products (27t28)	1.3	2.1	1.9	0.2	0.0	0.0	0.0
Machinery, nec (29)	1.0	2.1	1.5	0.5	0.0	0.0	0.0
Electrical and optical equipment (30t33)	2.8	4.8	3.2	1.4	0.0	0.1	0.1
Transport equipment (34t35)	0.9	2.0	1.4	0.5	0.0	0.0	0.0
Manufacturing nec, recycling (36t37)	2.7	3.6	3.3	0.2	0.0	0.0	0.0
Electricity, gas and water supply (E)	0.3	0.4	0.4	0.0	0.0	0.0	0.0
Construction (F)	0.9	1.6	1.3	0.3	0.0	0.0	0.0
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	0.0	0.2	0.1	0.0	0.0	0.0	0.0
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	1.4	2.0	1.7	0.3	0.0	0.0	0.0
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	2.0	2.1	2.1	0.0	0.0	0.0	0.0
Hotels and restaurants (H)	0.5	0.8	0.8	0.1	0.0	0.0	0.0
Transport and storage (60t63)	-0.1	0.1	0.0	0.1	0.0	0.0	0.0
Post and telecommunications (64)	0.8	1.0	0.9	0.0	0.0	0.0	0.0
Financial intermediation (J)	-1.4	-1.3	-1.4	0.1	0.0	0.0	0.0
Real estate activities (70)	0.1	0.2	0.2	0.0	0.0	0.0	0.0
Renting of machinery and equipment and other business activities (71t74)	0.5	0.8	0.8	0.1	0.0	0.0	0.0
Public admin and defence, compulsory social security (L)	0.2	0.5	0.4	0.1	0.0	0.0	0.0
Education (M)	-0.5	-0.4	-0.4	0.0	0.0	0.0	0.0
Health and social work (N)	-0.4	-0.1	-0.3	0.2	0.0	0.0	0.0
Other community, social and personal services (O)	-0.5	-0.2	-0.4	0.1	0.0	0.0	0.0
Private households with employed persons (P)	6.2	6.2	6.2	0.0	0.0	0.0	0.0

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

**Table 8****Country origin of multifactor productivity growth by industry, Canada, 2000 to 2007**

World Input-Output Database industry name (code)	Country contribution to effective MFP						
	Standard MFP	Effective MFP	Canada	United States	Australia	Japan	European Union
				percent			
Agriculture, hunting, forestry and fishing (AtB)	0.8	1.2	1.1	0.1	0.0	0.0	0.0
Mining and quarrying (C)	-3.3	-3.3	-3.4	0.0	0.0	0.0	0.0
Food products, beverages and tobacco (15t16)	0.0	0.5	0.4	0.1	0.0	0.0	0.0
Textiles, textile products, leather and footwear (17t19)	-0.9	-0.6	-0.8	0.2	0.0	0.0	0.0
Wood and products of wood and cork (20)	1.3	2.0	1.9	0.1	0.0	0.0	0.0
Pulp, paper, paper products, printing and publishing (21t22)	0.2	0.6	0.5	0.1	0.0	0.0	0.0
Coke, refined petroleum products and nuclear fuel (23)	-0.6	-2.0	-2.0	0.0	0.0	0.0	0.0
Chemical and chemical products (24)	0.0	0.1	-0.1	0.1	0.0	0.0	0.0
Rubber and plastic products (25)	0.0	0.3	0.1	0.1	0.0	0.0	0.0
Other non-metallic mineral products (26)	0.7	0.7	0.7	0.0	0.0	0.0	0.0
Basic metals and fabricated metal products (27t28)	0.4	0.4	0.5	-0.1	0.0	0.0	0.0
Machinery, nec (29)	0.3	0.9	0.5	0.3	0.0	0.0	0.0
Electrical and optical equipment (30t33)	-1.5	-0.6	-1.4	0.6	0.0	0.1	0.1
Transport equipment (34t35)	-0.1	0.7	0.0	0.5	0.0	0.1	0.1
Manufacturing nec, recycling (36t37)	-0.3	0.2	0.0	0.2	0.0	0.0	0.0
Electricity, gas and water supply (E)	0.6	0.4	0.4	0.0	0.0	0.0	0.0
Construction (F)	0.0	0.2	0.1	0.1	0.0	0.0	0.0
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	1.9	2.0	2.0	0.0	0.0	0.0	0.0
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	1.3	1.6	1.4	0.2	0.0	0.0	0.0
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	0.9	1.0	1.0	0.0	0.0	0.0	0.0
Hotels and restaurants (H)	-0.1	0.1	0.1	0.0	0.0	0.0	0.0
Transport and storage (60t63)	0.1	0.1	0.0	0.1	0.0	0.0	0.0
Post and telecommunications (64)	2.4	2.5	2.5	0.0	0.0	0.0	0.0
Financial intermediation (J)	0.1	0.3	0.2	0.0	0.0	0.0	0.0
Real estate activities (70)	-0.3	-0.2	-0.2	0.0	0.0	0.0	0.0
Renting of machinery and equipment and other business activities (71t74)	-0.2	0.1	0.0	0.1	0.0	0.0	0.0
Public admin and defence, compulsory social security (L)	0.1	0.2	0.1	0.1	0.0	0.0	0.0
Education (M)	0.2	0.3	0.2	0.0	0.0	0.0	0.0
Health and social work (N)	-0.6	-0.3	-0.5	0.1	0.0	0.0	0.0
Other community, social and personal services (O)	-0.3	-0.1	-0.2	0.1	0.0	0.0	0.0
Private households with employed persons (P)	-0.3	-0.3	-0.3	0.0	0.0	0.0	0.0

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

**Table 9****Country origin of multifactor productivity growth by industry, the United States, 1995 to 2000**

World Input-Output Database industry name (code)	Country contribution to effective MFP						
	Standard MFP	Effective MFP	Canada	United States	Australia	Japan	European Union
				percent			
Agriculture, hunting, forestry and fishing (AtB)	1.8	2.7	0.0	2.7	0.0	0.0	0.0
Mining and quarrying (C)	-2.0	-1.9	0.0	-1.9	0.0	0.0	0.0
Food products, beverages and tobacco (15t16)	-0.7	0.4	0.0	0.3	0.0	0.0	0.0
Textiles, textile products, leather and footwear (17t19)	0.9	1.9	0.0	1.8	0.0	0.0	0.0
Wood and products of wood and cork (20)	-0.1	1.0	0.1	0.9	0.0	0.0	0.0
Pulp, paper, paper products, printing and publishing (21t22)	-0.3	0.3	0.0	0.2	0.0	0.0	0.0
Coke, refined petroleum products and nuclear fuel (23)	0.0	-0.5	0.0	-0.4	0.0	0.0	0.0
Chemical and chemical products (24)	-0.9	-0.4	0.0	-0.5	0.0	0.0	0.0
Rubber and plastic products (25)	1.0	1.7	0.0	1.6	0.0	0.0	0.0
Other non-metallic mineral products (26)	0.4	0.8	0.0	0.8	0.0	0.0	0.0
Basic metals and fabricated metal products (27t28)	0.7	1.7	0.0	1.6	0.0	0.0	0.0
Machinery, nec (29)	-0.8	0.6	0.0	0.5	0.0	0.0	0.0
Electrical and optical equipment (30t33)	9.2	11.5	0.0	11.4	0.0	0.1	0.0
Transport equipment (34t35)	0.1	1.6	0.1	1.5	0.0	0.0	0.0
Manufacturing nec, recycling (36t37)	2.4	3.4	0.1	3.3	0.0	0.0	0.0
Electricity, gas and water supply (E)	0.1	-0.1	0.0	-0.1	0.0	0.0	0.0
Construction (F)	-0.8	0.0	0.0	0.0	0.0	0.0	0.0
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	0.8	1.4	0.0	1.4	0.0	0.0	0.0
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	5.0	5.2	0.0	5.2	0.0	0.0	0.0
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	3.1	3.3	0.0	3.3	0.0	0.0	0.0
Hotels and restaurants (H)	0.4	0.8	0.0	0.8	0.0	0.0	0.0
Transport and storage (60t63)	0.1	0.3	0.0	0.3	0.0	0.0	0.0
Post and telecommunications (64)	-0.7	-0.5	0.0	-0.5	0.0	0.0	0.0
Financial intermediation (J)	1.2	1.6	0.0	1.6	0.0	0.0	0.0
Real estate activities (70)	0.1	0.2	0.0	0.2	0.0	0.0	0.0
Renting of machinery and equipment and other business activities (71t74)	-0.9	-0.8	0.0	-0.8	0.0	0.0	0.0
Public admin and defence, compulsory social security (L)	-0.4	-0.1	0.0	-0.1	0.0	0.0	0.0
Education (M)	-0.8	-0.6	0.0	-0.6	0.0	0.0	0.0
Health and social work (N)	-1.1	-0.7	0.0	-0.7	0.0	0.0	0.0
Other community, social and personal services (O)	-0.6	-0.5	0.0	-0.5	0.0	0.0	0.0
Private households with employed persons (P)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

**Table 10**
**Country origin of multifactor productivity growth by industry, the United States, 2000 to 2007**

World Input-Output Database industry name (code)	Country contribution to effective MFP						
	Standard MFP	Effective MFP	Canada	United States	Australia	Japan	European Union
	percent						
Agriculture, hunting, forestry and fishing (AtB)	0.6	1.0	0.0	1.0	0.0	0.0	0.0
Mining and quarrying (C)	-2.3	-2.3	0.0	-2.3	0.0	0.0	0.0
Food products, beverages and tobacco (15t16)	-0.6	-0.2	0.0	-0.2	0.0	0.0	0.0
Textiles, textile products, leather and footwear (17t19)	1.3	2.1	0.0	2.0	0.0	0.0	0.0
Wood and products of wood and cork (20)	0.7	1.4	0.0	1.3	0.0	0.0	0.0
Pulp, paper, paper products, printing and publishing (21t22)	0.1	0.6	0.0	0.5	0.0	0.0	0.0
Coke, refined petroleum products and nuclear fuel (23)	0.1	-0.7	-0.2	-0.6	0.0	0.0	0.0
Chemical and chemical products (24)	0.4	0.7	0.0	0.7	0.0	0.0	0.0
Rubber and plastic products (25)	0.1	0.6	0.0	0.6	0.0	0.0	0.0
Other non-metallic mineral products (26)	-0.5	-0.4	0.0	-0.4	0.0	0.0	0.0
Basic metals and fabricated metal products (27t28)	-0.8	-0.7	0.0	-0.7	0.0	0.0	0.0
Machinery, nec (29)	1.1	1.7	0.0	1.6	0.0	0.0	0.0
Electrical and optical equipment (30t33)	6.7	7.8	0.0	7.7	0.0	0.1	0.0
Transport equipment (34t35)	1.1	2.0	0.0	1.9	0.0	0.1	0.0
Manufacturing nec, recycling (36t37)	1.9	2.4	0.0	2.3	0.0	0.0	0.0
Electricity, gas and water supply (E)	0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
Construction (F)	-2.5	-2.2	0.0	-2.2	0.0	0.0	0.0
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	-0.8	-0.4	0.0	-0.5	0.0	0.0	0.0
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	1.4	1.6	0.0	1.6	0.0	0.0	0.0
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	0.6	0.8	0.0	0.8	0.0	0.0	0.0
Hotels and restaurants (H)	0.4	0.6	0.0	0.6	0.0	0.0	0.0
Transport and storage (60t63)	0.9	1.2	0.0	1.2	0.0	0.0	0.0
Post and telecommunications (64)	2.8	3.3	0.0	3.3	0.0	0.0	0.0
Financial intermediation (J)	0.0	0.2	0.0	0.2	0.0	0.0	0.0
Real estate activities (70)	0.6	0.6	0.0	0.6	0.0	0.0	0.0
Renting of machinery and equipment and other business activities (71t74)	0.1	0.4	0.0	0.3	0.0	0.0	0.0
Public admin and defence, compulsory social security (L)	-0.2	0.0	0.0	0.0	0.0	0.0	0.0
Education (M)	-1.0	-0.8	0.0	-0.8	0.0	0.0	0.0
Health and social work (N)	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
Other community, social and personal services (O)	-0.7	-0.5	0.0	-0.5	0.0	0.0	0.0
Private households with employed persons (P)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

## 4.7 Productivity growth and international competitiveness

It is argued in Subsection 2.3 that the effective rate of MFP growth for the production of final products is a more appropriate measure of international competitiveness. For example, De Juan and Febrero (2000) show that, in Spain, effective MFP growth is more closely related to changes in output prices across industries than is standard MFP growth.

To examine the relationship between MFP growth and international competitiveness, a regression that expresses changes in gross output prices in industry  $i$  over a period  $t$  ( $\Delta \ln P_{i,t}$ ) is estimated as a function of standard MFP ( $v_{i,t}$ ), and another regression that expresses changes in gross output prices is estimated as function of effective MFP 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  $\alpha_t$  and  $\beta_t$  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  $\beta_1$  on the effective MFP growth variable will be closer to minus one than the coefficient  $\alpha_1$  on the standard MFP growth variable. R-squared should be higher for the regression on effective MFP growth.

The results in Table 11 show that, except for the EU countries, the R-squared from the regression on effective MFP growth ( $\beta_1$ ) is higher than the R-squared from the regression on standard MFP growth ( $\alpha_1$ ). 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.

**Table 11**  
**Explanation of changes in output prices by standard versus effective multifactor productivity growth measures**

	Canada	United States	Australia	Japan	European Union
<b>Estimation of Equation 16<sup>1</sup></b>					
Coefficient alpha 1	-0.78 *	-1.20 *	-1.20 *	-1.25 *	-0.90 *
R squared	0.17	0.66	0.31	0.43	0.26
t-statistic	-3.49	-9.78	-3.67	-6.38	-4.11
Number of observations	62	60	60	60	60
<b>Estimation of Equation 17<sup>2</sup></b>					
Coefficient beta 1	-0.95 *	-1.13 *	-1.21 *	-1.09 *	-0.77 *
R squared	0.32	0.74	0.33	0.46	0.25
t-statistic	-5.29	-12.31	-4.07	-6.77	-4.07
Number of observations	62	62	62	60	62

\* significantly different from reference category (p<0.05)

1. Equation for standard multifactor productivity growth.

2. Equation for effective multifactor productivity growth.

**Note:** Authors' tabulation based on data from the sources below.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

The evidence from the coefficient estimates on the MFP growth variables for Canada, the United States and Japan is consistent with the hypothesis that effective MFP growth is a better indicator of 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 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.



## 5 Conclusion

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

This analysis shows that a substantial portion of MFP growth, especially for small, open economies like Canada's, originates from 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 United States) was higher, Canada benefited more from productivity gains in foreign countries than did the other countries in the analysis. The foreign contribution to Canada's MFP growth increased from 24% in the 1995-to-2000 period, to 65% in the 2000-to-2007 period.

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.

Technical progress and productivity growth in foreign countries made a larger contribution to MFP growth for investment and export products, compared with consumption products. This is because domestic industries producing investment and exports are more integrated with industries in foreign countries and tend to have higher productivity growth than do consumption-product industries.

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

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

This analysis is based on the EU KLEMS productivity database and the WIOT. 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 as the EU KLEMS (Jorgenson 2012) and the WIOT (Timmer 2012) is essential for the development of our understating of the sources of international competitiveness and productivity growth.

## 6 Appendix

**Table 12**

**Average annual growth in standard and effective MFP growth for final demand products, assuming MFP for rest of world equals that of the United States, by country, 1995 to 2000 and 2000 to 2007**

	Standard MFP growth	Effective MFP growth
	percent	
<b>1995 to 2000</b>		
Canada	0.94	0.96
United States	0.85	1.01
Australia	0.97	0.98
Japan	0.31	0.31
European Union	0.38	0.44
<b>2000 to 2007</b>		
Canada	-0.04	0.34
United States	0.45	0.47
Australia	-0.53	-0.09
Japan	1.34	1.23
European Union	0.35	0.37

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

**Table 13****Effective multifactor productivity growth and expenditure shares by industry, Canada, 1995 to 2000**

World Input-Output Database industry name (code)	Effective MFP growth	Share of imported intermediates in gross output	Expenditure share by industry			
			Total final demand	Consumption	Investment	Export
			percent			
Agriculture, hunting, forestry and fishing (AtB)	2.30	0.06	0.01	0.01	0.00	0.03
Mining and quarrying (C)	-1.37	0.04	0.01	0.01	0.00	0.10
Food products, beverages and tobacco (15t16)	1.19	0.06	0.05	0.07	0.00	0.04
Textiles, textile products, leather and footwear (17t19)	1.82	0.14	0.01	0.01	0.00	0.02
Wood and products of wood and cork (20)	2.79	0.04	0.00	0.00	0.00	0.04
Pulp, paper, paper products, printing and publishing (21t22)	1.90	0.08	0.01	0.01	0.01	0.08
Coke, refined petroleum products and nuclear fuel (23)	-0.17	0.23	0.01	0.01	0.00	0.02
Chemical and chemical products (24)	1.84	0.12	0.01	0.01	0.00	0.05
Rubber and plastic products (25)	1.94	0.15	0.01	0.00	0.01	0.03
Other non-metallic mineral products (26)	2.34	0.10	0.00	0.00	0.00	0.01
Basic metals and fabricated metal products (27t28)	2.08	0.15	0.01	0.00	0.02	0.08
Machinery, nec (29)	2.11	0.15	0.01	0.00	0.04	0.03
Electrical and optical equipment (30t33)	4.78	0.25	0.02	0.00	0.08	0.08
Transport equipment (34t35)	1.97	0.26	0.09	0.04	0.24	0.24
Manufacturing nec, recycling (36t37)	3.56	0.13	0.01	0.01	0.01	0.03
Electricity, gas and water supply (E)	0.40	0.03	0.02	0.02	0.00	0.01
Construction (F)	1.60	0.11	0.10	0.00	0.47	0.00
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	0.18	0.02	0.00	0.00	0.00	0.00
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	2.05	0.10	0.02	0.02	0.02	0.00
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	2.14	0.03	0.04	0.04	0.02	0.01
Hotels and restaurants (H)	0.84	0.03	0.04	0.05	0.00	0.02
Transport and storage (60t63)	0.10	0.05	0.03	0.04	0.01	0.03
Post and telecommunications (64)	0.99	0.02	0.01	0.02	0.00	0.00
Financial intermediation (J)	-1.30	0.03	0.07	0.09	0.01	0.01
Real estate activities (70)	0.21	0.01	0.10	0.13	0.01	0.01
Renting of machinery and equipment and other business activities (71t74)	0.84	0.03	0.01	0.01	0.02	0.03
Public admin and defence, compulsory social security (L)	0.49	0.04	0.14	0.18	0.00	0.00
Education (M)	-0.36	0.01	0.06	0.08	0.00	0.00
Health and social work (N)	-0.07	0.03	0.05	0.07	0.00	0.00
Other community, social and personal services (O)	-0.19	0.07	0.04	0.05	0.00	0.01
Private households with employed persons (P)	6.23	0.00	0.00	0.00	0.00	0.00

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

**Table 14****Effective multifactor productivity growth and expenditure shares by industry, Canada, 2000 to 2007**

World Input-Output Database industry name (code)	Effective MFP growth	Share of imported intermediates in gross output	Expenditure share by industry			
			Total final demand	Consumption	Investment	Export
			percent			
Agriculture, hunting, forestry and fishing (AtB)	1.21	0.07	0.01	0.01	0.00	0.03
Mining and quarrying (C)	-3.30	0.03	0.01	0.01	0.00	0.14
Food products, beverages and tobacco (15t16)	0.49	0.07	0.05	0.06	0.00	0.04
Textiles, textile products, leather and footwear (17t19)	-0.60	0.17	0.01	0.01	0.00	0.02
Wood and products of wood and cork (20)	2.00	0.05	0.00	0.00	0.00	0.03
Pulp, paper, paper products, printing and publishing (21t22)	0.60	0.09	0.01	0.01	0.01	0.05
Coke, refined petroleum products and nuclear fuel (23)	-2.00	0.21	0.01	0.02	0.00	0.03
Chemical and chemical products (24)	0.10	0.16	0.01	0.01	0.00	0.05
Rubber and plastic products (25)	0.32	0.18	0.01	0.00	0.01	0.03
Other non-metallic mineral products (26)	0.69	0.09	0.00	0.00	0.00	0.01
Basic metals and fabricated metal products (27t28)	0.39	0.21	0.01	0.00	0.02	0.09
Machinery, nec (29)	0.85	0.17	0.01	0.00	0.04	0.04
Electrical and optical equipment (30t33)	-0.61	0.24	0.02	0.00	0.07	0.07
Transport equipment (34t35)	0.71	0.31	0.08	0.04	0.19	0.21
Manufacturing nec, recycling (36t37)	0.16	0.14	0.01	0.01	0.01	0.03
Electricity, gas and water supply (E)	0.45	0.04	0.01	0.02	0.00	0.01
Construction (F)	0.23	0.11	0.12	0.00	0.51	0.00
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	2.00	0.02	0.00	0.00	0.00	0.00
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	1.64	0.10	0.03	0.02	0.03	0.00
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	0.99	0.03	0.04	0.05	0.02	0.01
Hotels and restaurants (H)	0.13	0.04	0.04	0.05	0.00	0.02
Transport and storage (60t63)	0.12	0.05	0.03	0.03	0.01	0.03
Post and telecommunications (64)	2.53	0.02	0.01	0.02	0.00	0.00
Financial intermediation (J)	0.27	0.03	0.07	0.09	0.02	0.01
Real estate activities (70)	-0.22	0.01	0.09	0.12	0.02	0.01
Renting of machinery and equipment and other business activities (71t74)	0.09	0.03	0.02	0.01	0.03	0.03
Public admin and defence, compulsory social security (L)	0.24	0.04	0.13	0.17	0.00	0.00
Education (M)	0.26	0.01	0.06	0.07	0.00	0.00
Health and social work (N)	-0.30	0.04	0.05	0.07	0.00	0.00
Other community, social and personal services (O)	-0.08	0.09	0.05	0.06	0.00	0.01
Private households with employed persons (P)	-0.27	0.00	0.00	0.00	0.00	0.00

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

**Table 15****Effective multifactor productivity growth and expenditure shares by industry, the United States, 1995 to 2000**

World Input-Output Database industry name (code)	Effective MFP growth	Share of imported intermediates in gross output	Expenditure share by industry			
			Total final demand	Consumption	Investment	Export
			percent			
Agriculture, hunting, forestry and fishing (AtB)	2.73	0.03	0.00	0.01	0.00	0.03
Mining and quarrying (C)	-1.86	0.04	0.00	0.00	0.01	0.01
Food products, beverages and tobacco (15t16)	0.36	0.05	0.04	0.04	0.00	0.04
Textiles, textile products, leather and footwear (17t19)	1.90	0.06	0.01	0.01	0.00	0.02
Wood and products of wood and cork (20)	1.04	0.04	0.00	0.00	0.01	0.01
Pulp, paper, paper products, printing and publishing (21t22)	0.26	0.05	0.01	0.01	0.02	0.03
Coke, refined petroleum products and nuclear fuel (23)	-0.47	0.27	0.01	0.01	0.00	0.01
Chemical and chemical products (24)	-0.44	0.07	0.01	0.01	0.00	0.07
Rubber and plastic products (25)	1.69	0.07	0.00	0.00	0.00	0.02
Other non-metallic mineral products (26)	0.84	0.05	0.00	0.00	0.00	0.01
Basic metals and fabricated metal products (27t28)	1.68	0.08	0.00	0.00	0.01	0.04
Machinery, nec (29)	0.61	0.09	0.02	0.00	0.08	0.08
Electrical and optical equipment (30t33)	11.54	0.11	0.03	0.01	0.09	0.18
Transport equipment (34t35)	1.59	0.10	0.03	0.02	0.10	0.12
Manufacturing nec, recycling (36t37)	3.39	0.07	0.01	0.01	0.02	0.02
Electricity, gas and water supply (E)	-0.06	0.06	0.01	0.02	0.00	0.00
Construction (F)	0.03	0.05	0.08	0.00	0.45	0.00
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	1.45	0.04	0.01	0.02	0.00	0.00
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	5.22	0.01	0.04	0.03	0.05	0.10
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	3.31	0.02	0.08	0.10	0.02	0.00
Hotels and restaurants (H)	0.80	0.02	0.04	0.05	0.00	0.00
Transport and storage (60t63)	0.26	0.02	0.02	0.02	0.01	0.07
Post and telecommunications (64)	-0.48	0.02	0.02	0.02	0.00	0.01
Financial intermediation (J)	1.58	0.01	0.06	0.07	0.00	0.06
Real estate activities (70)	0.19	0.01	0.11	0.12	0.03	0.00
Renting of machinery and equipment and other business activities (71t74)	-0.76	0.02	0.03	0.02	0.09	0.06
Public admin and defence, compulsory social security (L)	-0.10	0.06	0.17	0.22	0.00	0.01
Education (M)	-0.60	0.00	0.01	0.01	0.00	0.00
Health and social work (N)	-0.72	0.01	0.10	0.12	0.00	0.00
Other community, social and personal services (O)	-0.46	0.01	0.04	0.05	0.00	0.01
Private households with employed persons (P)	0.00	0.00	0.00	0.00	0.00	0.00

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

**Table 16****Effective multifactor productivity growth and expenditure shares by industry, the United States, 2000 to 2007**

World Input-Output Database industry name (code)	Effective MFP growth	Share of imported intermediates in gross output	Expenditure share by industry			
			Total final demand	Consumption	Investment	Export
			percent			
Agriculture, hunting, forestry and fishing (AtB)	0.97	0.04	0.00	0.01	0.00	0.02
Mining and quarrying (C)	-2.28	0.06	0.01	0.00	0.03	0.01
Food products, beverages and tobacco (15t16)	-0.15	0.05	0.03	0.04	0.00	0.03
Textiles, textile products, leather and footwear (17t19)	2.05	0.07	0.00	0.00	0.00	0.01
Wood and products of wood and cork (20)	1.41	0.04	0.00	0.00	0.00	0.00
Pulp, paper, paper products, printing and publishing (21t22)	0.57	0.06	0.01	0.01	0.02	0.03
Coke, refined petroleum products and nuclear fuel (23)	-0.72	0.32	0.01	0.01	0.00	0.02
Chemical and chemical products (24)	0.75	0.09	0.01	0.01	0.00	0.07
Rubber and plastic products (25)	0.62	0.09	0.00	0.00	0.00	0.02
Other non-metallic mineral products (26)	-0.36	0.05	0.00	0.00	0.00	0.01
Basic metals and fabricated metal products (27t28)	-0.70	0.10	0.00	0.00	0.01	0.04
Machinery, nec (29)	1.70	0.11	0.02	0.00	0.07	0.08
Electrical and optical equipment (30t33)	7.77	0.12	0.02	0.01	0.07	0.16
Transport equipment (34t35)	2.00	0.13	0.03	0.02	0.09	0.13
Manufacturing nec, recycling (36t37)	2.36	0.08	0.01	0.00	0.02	0.02
Electricity, gas and water supply (E)	-0.14	0.11	0.01	0.02	0.00	0.00
Construction (F)	-2.15	0.06	0.09	0.00	0.45	0.00
Sales, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50)	-0.42	0.04	0.01	0.02	0.00	0.00
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	1.58	0.02	0.04	0.03	0.05	0.10
Retail trade, except of motor vehicles and motorcycles, repair of household goods (52)	0.76	0.02	0.08	0.09	0.02	0.00
Hotels and restaurants (H)	0.58	0.03	0.04	0.05	0.00	0.00
Transport and storage (60t63)	1.18	0.03	0.02	0.02	0.01	0.07
Post and telecommunications (64)	3.29	0.02	0.02	0.02	0.00	0.01
Financial intermediation (J)	0.23	0.02	0.06	0.07	0.00	0.07
Real estate activities (70)	0.63	0.01	0.11	0.12	0.03	0.00
Renting of machinery and equipment and other business activities (71t74)	0.35	0.02	0.04	0.02	0.11	0.07
Public admin and defence, compulsory social security (L)	-0.03	0.08	0.17	0.21	0.00	0.01
Education (M)	-0.80	0.00	0.01	0.01	0.00	0.00
Health and social work (N)	0.03	0.01	0.10	0.12	0.00	0.00
Other community, social and personal services (O)	-0.52	0.02	0.04	0.05	0.00	0.01
Private households with employed persons (P)	0.00	0.00	0.00	0.00	0.00	0.00

**Notes:** Authors' tabulation based on data from the sources below. MFP: multifactor productivity; nec: not elsewhere classified.

**Sources:** World Input-Output Database; and EU KLEMS productivity database.

## References

- Altomonte, C., and G.P. Ottaviano. 2011. "The Role of International Production Sharing in EU Productivity and Competitiveness." *European Investment Banks Papers* 16 (11): 63–88.
- Aulin-Ahmavaara, P. 1999. "Effective Rates of Sectoral Productivity Change." *Economic Systems Research* 11 (4): 349–363.
- Baldwin, J.R., R. Durand, and J. Hosein. 2001. "Restructuring and Productivity Growth in the Canadian Business Sector." In *Productivity Growth in Canada*, Chapter 2: 22–38, Statistics Canada Catalogue no.15-204-X. Ottawa: Statistics Canada.
- Baldwin J.R., and W. Gu. 2008. *Outsourcing and Offshoring in Canada*. Economic Analysis Research Paper Series, no. 55. Statistics Canada Catalogue no. 11F0027M. Ottawa: Statistics Canada.
- Baldwin, J.R., W. Gu, A. Sydor and B. Yan. 2013. "Material Offshoring: Alternative Measures." Economic Analysis Research Paper Series, no. 86. Statistics Canada Catalogue no. 11F0027M. Ottawa: Statistics Canada.
- Ball, V.E., J.-P. Butault, C.S. Juan, and R. Mora. 2010. "Productivity and international competitiveness of agriculture in the European Union and United States." *Agricultural Economics* 41 (6): 611–627.
- Basu S., J. Fernald, J. Fisher, and M. Kimball. 2010. *Sector-Specific Technical Change*. Boston: Boston College, Federal Reserve Bank of San Francisco and Federal Reserve Bank of Chicago.
- Cas, A., and T.K. Rymes. 1991. *On Concepts and Measures of Multifactor Productivity in Canada, 1961-1980*. Cambridge, United Kingdom: Cambridge University Press.
- Coe, D.T., and E. Helpman. 1995. "International R&D spillovers." *European Economic Review* 39: 859–887.
- De Juan, O., and E. Ferbrero. 2000. "Measuring productivity from vertically integrated sectors." *Economic Systems Research* 12 (1): 65–82.
- Diewert, E.W. 1976. "Exact and superlative index numbers." *Journal of Econometrics* 4 (2):115–156.
- Diewert, E.W., and E. Yu. 2012. "New estimates of real income and multifactor productivity growth for the Canadian business sector, 1961-2001." *International Productivity Monitor* 12: 27–48.
- Domar, E. 1961. "On the measurement of technical change." *Economic Journal* 71: 710–729.
- Durand, R. 1996. "Canadian input-output-based multifactor productivity accounts." *Economic Systems Research* 8 (4): 367–390.
- Feenstra, R.C., and J.B. Jensen. 2012. *Evaluating Estimates of Materials Offshoring from U.S. Manufacturing*. NBER Working Paper Series, no. 17916. Cambridge, Massachusetts: National Bureau of Economic Research.
- Gu, W. 2012. "Estimating capital input for measuring business sector multifactor productivity growth in Canada: response to Diewert and Yu." *International Productivity Monitor* 12: 49–62.

- Gu, W., and L. Whewell. 2005. "The effect of trade on productivity growth and the demand for skilled workers in Canada." *Economic Systems Research* 17 (3): 279–296
- Hulten, C.R. 1978. "Growth Accounting with Intermediate Inputs." *Review of Economic Studies* 45 (10): 511–518.
- Jorgenson, D.W. 2012. "World KLEMS Initiative." *International Productivity Monitor* 24: 5–19.
- Jorgenson, D.W., and Z. Griliches. 1967. "The explanation of productivity change." *The Review of Economic Studies* 34: 249–283.
- Jorgenson, D.W., M.S. Ho, J.D. Samuels, and K.J. Stiroh. 2007. "Industry origins of the American productivity resurgence." *Economic Systems Research* 19 (3): 229–252.
- Jorgenson, D.W., and M. Nishimizu. 1978. "U.S. and Japanese economic growth, 1952-1974: An international comparison." *Economic Journal* 88 (352): 707–726.
- Johnson, R.C., and G. Noguera. 2011. "Accounting for intermediates: Production sharing and trade in value added." *Journal of International Economics* 86 (2): 224–236.
- Koopman, R., Z. Wang, and S.-J. Wei. 2012. "Estimating domestic content in exports when processing trade is pervasive." *Journal of Development Economics* 99 (1): 178–189.
- Lee, F. and J. Tang. 2000. "Productivity levels and international competitiveness between Canadian and U.S. industries." *American Economic Review* 90 (2): 176–179.
- Leontief, W. 1936. "Quantitative input-output relations in the economic system of the United States." *Review of Economics and Statistics* 18: 105–125.
- Organisation for Economic Co-operation and Development (OECD). 2012. *Trade Policy Implications of Global Value Chains*. Paris: Organisation for Economic Co-operation and Development.
- Oliner, S.D., D.E. Sichel, and K.J. Stiroh. 2007. *Explaining a Productivity Decade*. Brookings Papers on Economic Activity, 81–152. Brookings Press.
- O'Mahony, M., and M.P. Timmer. 2009. "Output, input and productivity measures at the industry level: the EU KLEMS database." *Economic Journal* 119 (538): F374–F403.
- Rymes, T.K. 1971. *On the Concepts of Capital and Technical Change*. Cambridge, United Kingdom: Cambridge University Press.
- Schreyer, P. 2012. "Comments on 'Estimating capital input for measuring business sector multifactor productivity growth in Canada'" *International Productivity Monitor* 12: 73–75
- Statistics Canada. 1994. *Aggregate Productivity Measures 1994. System of National Accounts*. Statistics Canada Catalogue no.15-204E. Ottawa: Statistics Canada.
- Timmer, M.P., A.A. Erumban, B. Los, R. Stehrer, and G. de Vries. 2012. *New Measures of European Competitiveness: A Global Value Chain Perspective*. Groningen, The Netherlands: Groningen Growth and Development Centre, University of Groningen.
- Timmer, M.P., ed. 2012. *The World Input-Output Database (WIOD): Contents, Sources and Methods*. WIOD Working Paper Number 10.



van Ark, B., V. Chen, B. Colijn, K. Jaeger, W. Overmeer, and M. Timmer. 2013. "Recent changes in Europe's competitive landscape and medium-term perspectives: how the sources of demand and supply are shaping up" *IARIW-UNSW Special Conference on "Productivity Measurement, Drivers and Trends,"* Sydney, Australia, November 26–27, 2013.

van Ark, B., M. O'Mahony, and M.P. Timmer. 2008. "The productivity gap between Europe and the United States: Trends, and causes." *Journal of Economic Perspectives* 22 (1): 25–44.

Wooldridge, J.M. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge: The MIT Press.

Yakabuski, K. "CETA's nice. NAFTA is essential." *The Globe and Mail*, October 28, 2013.